Semi-Automatic Quantification of Late Enhancement in CT and MRI Images

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Introduction: Myocardial viability assessment is an important task in the diagnosis of coronary heart disease. The measurement of the late enhancement (LE) effect, the accumulation of contrast agent in defective tissue, has become the gold standard for detecting necrotic tissue with MRI. Studies have shown, that this effect can be observed for iodine-based contrast agents, which are used for CT coronary artery imaging, as well [1,2]. In order to save examination time, imaging is performed as early as possible, and in the centers of necrotic regions so-called microvascular obstructions (MVOs) as shown in Fig. 1 are likely to be seen. This hinders the usage of the typical threshold-based quantification methods, and thus most comparison studies are based on manual delineation. The purpose of this work was to evaluate how reproducible LE tissue can be identified semi-automatically in CT and MRI data with a mixture model approach and additional closing step for the inclusion of MVOs. To this end, CT and MRI datasets of seven pigs with inflicted infarctions were analyzed with the proposed method. Results were compared regarding location an volumes of the detected regions.

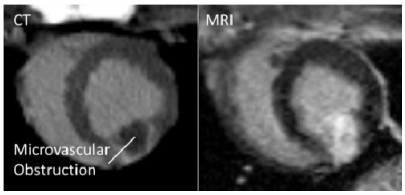

Figure 1. CT and MRI images of the same subject. The CT image shows a large region of MVO whereas the corresponding region of the MR image appears completely bright.

Methods: 7 pigs received inflicted myocardial infarctions 60 min prior to image acquisition. MR images were acquired 10 min after the injection of a gadolinium-based contrast agent (Magnevist, Bayer-Schering) in short-axis orientation at 1.5T (Philips Gyroscan Intera) with a resolution of 1.484x 1.484x6.mm³. CT imaging was performed with a 64-slice Dual Source CT Scanner (Siemens Definition) 10 min after the administration of an iodine-based contrast agent (Ultravist 300, Bayer-Schering). CT mages were reconstructed with a smooth kernel (B20f) in short-axis orientation with a resolution of 0.391x0.391x6.mm³. The automatic segmentation was performed with a method that combines an analysis of the myocardial intensity distribution with assumptions about location and size of relevant infarctions. A partial volume model is derived from a mixture model fit to the myocardium's histogram. For MRI data, a mixture of a Rice distribution and a Gauss distribution is assumed [3], whereas for CT data the intensity distribution is modeled as a mixture of two Gaussians. The segmentation is performed with a watershed segmentation, where those sinks are selected, which are located in the inner part of the myocardium [4]. Additional seedpoints can be defined manually. To add the dark MVO regions to the segmentation and assure that the partial volume voxels at the transition between MVO and enhanced tissue, the formula shown in Fig. 2 is applied. The segmentation methods are integrated in a software application, which can be applied to both CT and MRI data.

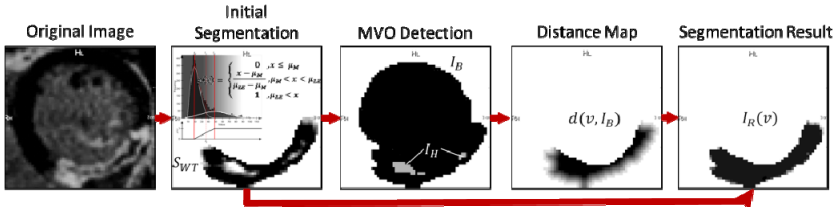

Figure 2. Segmentation of MVO regions. The inclusion of MVO regions $\boldsymbol{I_H}$ is based on the distance from the segmentation border, and the LE volume $\boldsymbol{V_{LE}}$ is computed as follows:

$$V_{LE} = \sum I_R(v) \text{ with } I_R(v) = \begin{cases} 1, & v \in S_{WT} \cup I_H \wedge d(v, I_B) > 3 \\ p(x), & v \in S_{WT} \cup I_H \wedge d(v, I_B) \leq 3 \\ 0, & v \notin S_{WT} \cup I_H \end{cases}$$

	CT	MR
1	18.40	20.98
2	11.52	11.30
3	15.44	16.05
4	9.51	11.41
5	12.46	12.54
6	5.61	3.86
7	9.48	11.86

Table 1. Volumetric results for corresponding CT and MRI datasets.

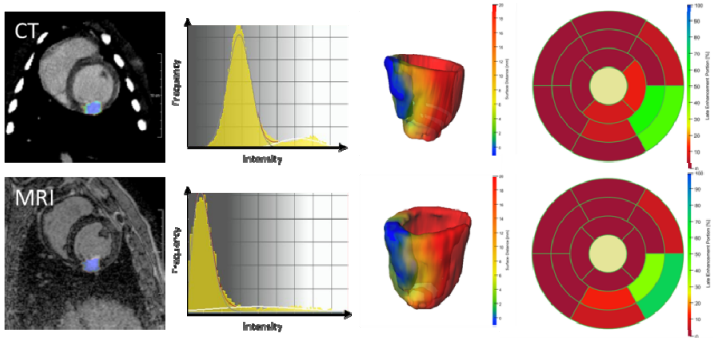

Figure 3. Segmentation results for case 7. The second column shows the mixture model fit. The 3D visualization depicts the segmented region(blue) in relation to the myocardium. The corresponding quantification results according to the AHA model are shown in the last column. The differences in the coverage of the myocardium segmentation cause different late enhancement segmentation results.

Results: The proposed method was applied successfully to all 14 datasets. The inflicted infarctions were detected automatically at the correct positions in all datasets, and no false positive regions were segmented. Additional seed points had to be placed interactively for the segmentation of the CT datasets of cases 4, 5 and 6 to extend the result. The volumes of the detected regions differed between 0.08 and 2.58ml (Ø1.3ml) in CT- and MRI-based segmentations as shown in Table 1. The largest differences were found for case 1 and 7 (see Fig. 3), where infarctions were located in the basal segments close to the valve planes. The differences in the coverage of the myocardium segmentation led to different results. The comparison of the segmentation surface distances after manual image fusion resulted in distance values between 0 and 3mm (see Fig. 4).

Discussion: We have presented a method for the objective quantification of LE for viability assessment in CT as well as in MRI datasets. The implemented tool has been successfully applied to datasets of animals with inflicted infarctions. Although CT segmentation required more interaction than MRI segmentation, the agreement of the volumetric results was very good. A major drawback of the presented method is the dependency on the preceeding myocardium segmentation, which became apparent for the infarctions located in the basal segments.

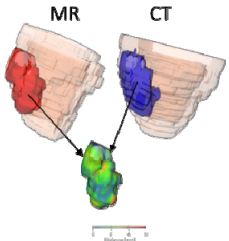

Figure 4. Comparison of the segmentation surfaces for case 3.

References

[1] Nieman, K., et al., Radiology 247, 2008
[2] Mahnken, AH., et al., JACC 2007
[3] Friman, O., et al., ISMRM 2007, Abstract 1040
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