A software tool for the combined analysis of angiographic and perfusion MRI datasets for an optimized diagnosis of Coronary Artery Disease

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Introduction

Diseases of the coronary arteries are the main cause of death in western countries. In particular, the so-called ischemia, the undersupply of the heart muscle with blood, has the most frequent occurrence. Typically, symptoms of the partial obstruction of a coronary artery range from an insufficient supply of corresponding myocardial areas to dysfunction of the heart muscle. For diagnosis and therapy planning morphological information as well as functional information is of high interest. Nowadays, the analysis of coronary arteries in clinical routine is normally based on the invasive catheter angiography or CT angiograms. Additionally, MR, SPECT or PET images are used to examine perfusion and viability. The acquisition of both, morphological and functional data from different modalities, is therefore time-consuming and only few software tools support a combined analysis [1][2][3] . Recent developments in MR acquisition technology now facilitate the acquisition of 3D volume data of the heart and thus the analysis of the patient individual coronary tree anatomy with high spatial resolution [4]. In this work an optimized post-processing scheme for the combined analysis of myocardial perfusion and topology of the supplying coronary artery based solely on MRI data is presented. This tool was in cooperation with clinical partners in the VICORA project.

Methods

Image Data: The described methods were applied to 5 datasets acquired in clinical routine at 1.5 Tesla (Siemens Avanto). Angiographic images were gathered with a ECG-triggered T2-prepared SSFP sequence covering the whole heart. For perfusion analysis, 3 to 4 short axis slices were acquired after injection of Gd-DTPA using a saturation recovery turbo flash 2D sequence. Late-enhancement images contain 8 to 10 slices, acquired with a inversion recovery turbo flash sequence. Two datasets contain arteries with stents and all patients suffer from coronary artery disease.

***Image Analysis and Visualization**:* For coronary artery segmentation, we adapted an algorithm originally designed for coronary tree segmentation in CT angiographic images. This algorithm is based on a region growing algorithm that incorporates model assumptions on the coronary tree topology [5]. After one click into the aorta a first automatic detection of the coronary arteries is performed. If the result is insufficient, it can be extended interactively. The result of this segmentation is then used to provide a 3D visualization and curved multi-planar reformatting of the coronaries. To analyze myocardial perfusion, AHA conform bulls-eye-plots as well as parameter images are derived from the motion corrected perfusion sequences. In these maps, showing the semi-quantitative parameters *upslope, area-under-curve, peak-enhancement,* and *time-to-peak,* suspicious regions can be identified by threshold based or manual segmentation [6]. The automatic detection of myocardial regions showing delayed enhancement is based on a user defined segmentation of the myocardium. The threshold for the detection of suspicious tissue is derived from an analysis of the intensity distribution in the myocardium region [7]. For the combined view of the results derived from the three different image types, the images are registered via the DICOM information.

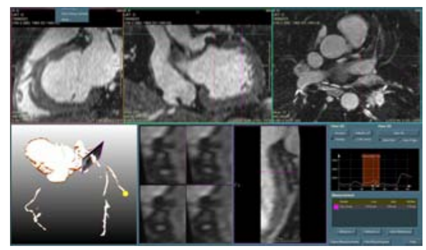

Fig. 1: Coronary artery analysis

Results

The described algorithms, which are integrated into a prototypical software package for clinical evaluation, were applied to the test set. In all datasets additional user interaction was necessary to achieve an adequate segmentation of the coronary tree. In image regions with strong blurring artefacts or stents no artery detection was possible (Fig. 1) and the visualization shows disruptions (Fig. 2). Motion Correction and extraction of semi-quantitative parameters could be successfully applied to all datasets. Threshold based segmentation of suspicious regions was performed on the two stress perfusion datasets of patients with stents. Figure 2 shows visualization results for a patient with stent, LAD stenosis and an infarct in the septal wall. The images show the result of the AHA-segment-model based late-enhancement-analysis. The result is visualized in the 2D bulls-eye-plot as well as in combination with the coronary arteries in 3D. The accurate segmentation result is shown as a surface rendering in figure 3. The perfusion slice with the parameter overlay is shown in 2D as well as in the 3D context. The red color indicates a low *area-under-curve* while green indicates a high value.

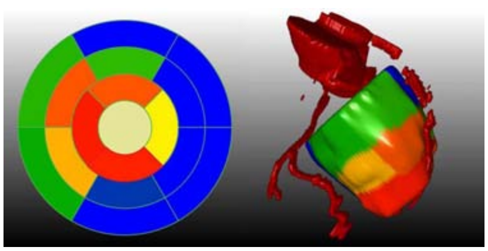

Fig. 1: Segment-based late-enhancement-analysis in bulls-eye-plot and in 3D

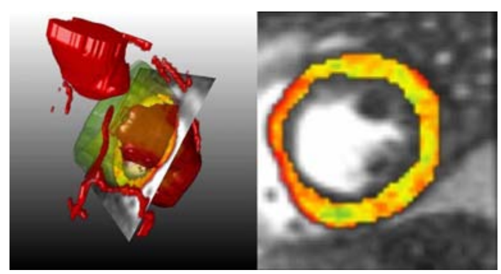

Fig. 3: Voxel-based analysis of late-enhancement and perfusion combined with the coronary tree segmentation

Discussion and Conclusions

We present a software package for the analysis of cardiac MR data considering both functional and anatomical information. For the first time, tools for the analysis of the coronary arteries, myocardial perfusion, and late enhancement in MR data were combined in order to allow a combined examination of topological correspondences in clinical data. Feasibility tests were conducted demonstrating the potential of the approach. The experiments also showed that the segmentation of the coronary arteries in datasets with artefacts still requires a considerable amount of user interaction and needs to be improved to facilitate use in clinical routine. Further steps will also include the computational analysis of the vascular dependencies of myocardial regions.

References

[1] Mullick R et al. *Multimodality Visualization of MR Functional Information Fused with CT Coronary Vasculature* Proc. ISMRM 14:788 (2006)

[2] Sturm et al. *Registration of 3D CT angiography & cardiac MR images in coronary artery disease patients.* Int J Cardiovasc Imaging 2003, 19: 281-293

[3] Kühnel C et al. *New Software Assistants for Cardiovascular Diagnosis.* 5.10.2006; Springer, 2006, pp. 491-498.

[4] Barkhausen J et al. *MR Evaluation of Ventricular Function: True Fast Imaging with Steady-State Precession versus Fast Low-Angle Shot Cine MR Imaging: Feasibility Study* Radiology, 219: 264 (2001)

[5] Hennemuth A et al. *One-click coronary tree segmentation in CT angiographic images.* Amsterdam: Elsevier, 2005, pp. 317-321.

[6] Hennemuth A et al. *Novel methods for parameter based analysis of myocardial tissue in MR-Images.* In SPIE, 2007

[7] Kolipake A et al. *Segmentation of non-viable myocardium in delayed enhancement magnetic resonance images.* In ISMRM, 2003