Coregistration and Visualization of Regionally Perfused Myocardium from First-Pass Multislice Sets based on Independent Components Analysis

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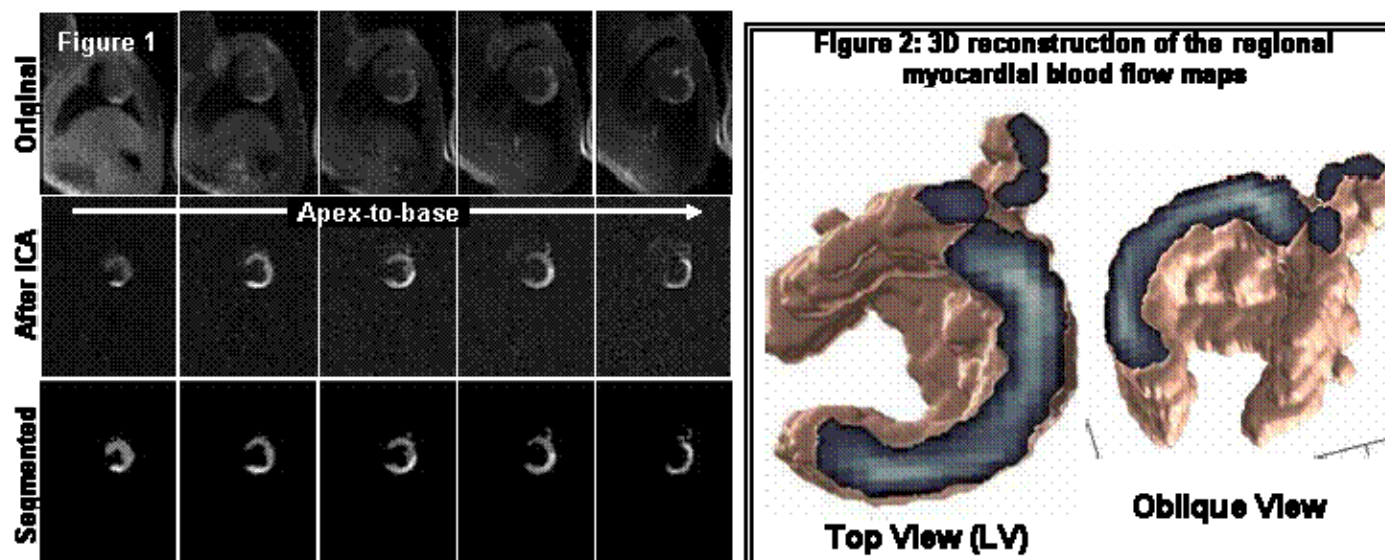
INTRODUCTION: Image segmentation and rendering of anatomical and functional MRI is an important and well studied area [1]. In cardiac imaging, semi-automated segmentation based on manual tracing of the anatomies and region-of-interests (ROI) is usually used [2]. In certain situations, however, automated segmentation would be beneficial to speed up processing and reduce the work load especially when used in the emerging MR-guided cardiac procedures and robot assisted interventions, or for pre-operative cardiac surgery planning. The purpose of this work is to investigate the segmentation of multislice first pass MR cardiac images and generate 3D renderings of perfused myocardium using the independent component analysis (ICA) [3-4].

METHODS:

Independent Component analysis; The dynamic first pass series was processed with the ICA method to correct for breathing motion and register all frames of the same slice [3-4]. ICA is a blind source separation method that has already been successfully applied to various problems in signal and image processing. ICA decomposes measured mixed signals into a set of statistically independent signals. The ICA model is formulated as $X \approx Xm + \Phi B$ where Φ stands for the independent components, B is the loading matrix and Xm is defined as the average image throughout time. Therefore, the Independent components depict perfusion territories with different dynamics, thereby segmenting differentially perfused areas (data set X_J; where J is the index of slice and $1 < J < N$).

3D Reconstruction: To generate 3D reconstructions of the perfused myocardium segmented by the ICA method, first, we interpolated the ICA results (X_J) along the long axis direction. An interpolation slice in-between two consecutive collected slice was generated by determining their respective centers of mass and then averaging at the mean of the center of masses of the two bounding slices creating a set Y_J where $1 < J < 2N-1$. The Y_J set was processed with the Otsu thresholding method to extract the background noise and then was dilated to smooth boundaries (non-dilated images were also tested). Finally, the reconstructed 3D image was generated from the processed Y_J set using the spatial information of the original files (position, pixel size, slice thickness and distance). The 3D shape was then smoothed with a Gaussian filter and caped with the first and last slices (original gray or a pseudo-color scale).

In Vivo Studies: The ICA-based 3D reconstruction was evaluated on in vivo studies performed on pigs (n=3) instrumented with an intracoronary catheter in the left main artery placed through a carotid access under x-ray fluoroscopy for infusion of Gd-DTPA and selective enhancement of perfused myocardial territories.. First pass imaging was performed with a multislice T1-prepared GRE sequence (TR/TE/α = 2.77/1.44/35°; FOV = 225x300mm; slice = 10mm; matrix = 96x128). [5]. The first pass series usually contained seven slices and up to 100 repetitions.

Figure 1 / Original / Apex-to-base / After ICA / Segmented

Figure 2: 3D reconstruction of the regional myocardial blood flow maps / Top View (LV) / Oblique View

RESULTS: The upper panel in Fig, 1 shows a selected time frame from the first pass time series depicting five slices (out of the seven collected) of the original multislice set. The middle panel shows the corresponding regionally perfused myocardium segmented using the ICA method. The implemented ICA algorithm efficiently coregistered each slice of the first pass multislice dynamic set while it corrected for breathing motion. The lower panel in Fig 1 shows the final segmented images used in the 3D reconstruction (after the Otsu segmentation). The employed method successfully segmented out the perfused myocardium (corresponding to the anterior and antero-lateral segments perfused in this particular animal by the main coronary artery). Figure 2 shows representative 3D reconstructions of the perfused myocardium maps viewed along the long axis of the left ventricle (LV), and from a posterior- to-anterior oblique perspective. Such automated technique can segment tissue on-the-fly that has certain functional and contrast attributes (e.g., ischemic or infracted myocardium). And can be fused and overlaid onto anatomical images to generate multi-parametric maps for planning and guiding an intervention. Work is underway to incorporate dynamic MR coronary angiography.

REFERENCES: (1) Pham et al Ann Rev Biomed Eng 2, 315-37 (2000); (2) Fenchel et al Inv. Radiology 39, 572-581 (2004); (3) Milles et al IEEE-TMI (2008); (4) Milles et al SPIE (2006) (5) Gui et al JMRI 24, 1151-8 (2006).