Knowledge-based Left Ventricle Segmentation and Partial Volume Calculation in Cardiac Cine MRI

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INTRODUCTION: It is highly desired to automatically segment ventricular blood and myocardium for quantification of cardiac output and myocardial mass in clinical practice, as existing software is typically problematic and labor intensive manually tracing is constantly used. Here we present a knowledge-based left ventricle (LV) segmentation and partial volume calculation algorithm to segment short-axis cine cardiac MRI. Coil sensitivity of magnitude image is corrected. Graph searching and expansion are applied to detect the myocardium (MC). We segment the left ventricle using a region-growing scheme and then calculated partial volume effects by a weighting function from statistics of the left ventricle and myocardium.

ALGORITHM: We have prior anatomical knowledge about short-axis cardiac MRI: LV is surrounded by MC, LV is circular, LV has similar signal intensity, MC has similar signal intensity, and LV has sharp signal intensity difference from MC. Using this knowledge, we design an algorithm for segmenting LV as shown in Fig. 1. (1) extract exact LV region from magnitude image by user input and strong region-growing constraint, (2) correct coil sensitivity and remove noisy variation, (3.1) generate circular map by polar mapping from corrected image, (3.2) estimate intensity statistics of LV and MC using edge detection and classification, (3.3) extract myocardium region by graph searching and expansion where graph are generated with intensity difference and gradient, (3.4) detect LV by region-growing scheme where the region-growing threshold comes from MC intensity statistics, (3.5) transform polar coordinate to image coordinate, (4) calculate normal and partial volume considering intensity statistics of LV and MC.

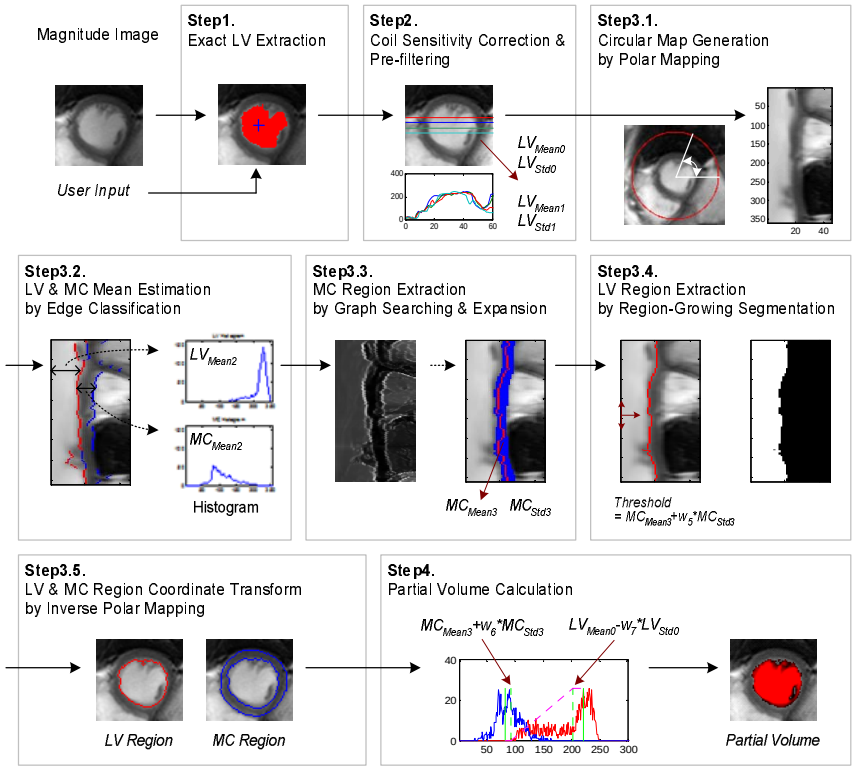

Fig. 1. Knowledge-based cardiac left ventricle and myocardium segmentation and partial volume calculation algorithm

MATERIALS AND METHODS: Cardiac cine SSFP scans were performed on 38 subjects with a GE Signa 1.5T scanner. A mean age of subjects was 52 years with range from 14 to 77. Total 635 images were segmented by our segmentation and manual contour tracing. Manual contour for the gold-standard was traced by professional experts (8 years and 3 years in CMR) with papillary and trabeculae muscles excluded from the blood volume.

RESULTS: We measured blood volume and ejection fraction of LV and myocardium mass using our segmentation and compared with manual contour tracing. Table 1 summarizes blood volume, ejection fraction, and epicardial volume of the 38 subjects. Since we consider partial volume effects, the blood volume of our segmentation is naturally smaller than manual contouring. Fig. 2 shows magnitude images, left ventricle, myocardium, partial volume image, and manual contouring. The automatic segmentation results agree well with the manual tracing results, as indicated by the high correlation values.

DISCUSSION: Because of the clear intensity difference between left ventricle and myocardium, the left ventricle is segmented without user intervention for all image slices. In a very small fraction of image slices where the intensity difference between myocardium and its surrounding tissue is small, the detected epicardial contour may extend beyond myocardium, causing errors in the measurement of ventricular wall mass. However, the blood volume and myocardial mass correlates well with that by manual contour tracing. The algorithmic error defined by the difference from manual contouring is smaller than the operator variability in manual contour tracing (~21.3 mL for myocardium mass). Further improvement may reduce or eliminate this error. Also, we will automate the segmentation process by extracting seed points automatically.

Table 1. Comparison results between manual contour tracing and our segmentation in 38 subjects.

	Manual contouring – Our segmentation		
	Absolute	Relative	Correlation
Diastolic volume	18.9±8.4 (mL)	13.1±3.6 (%)	R^2=0.98
Systolic volume	9.8±6.5 (mL)	18.2±6.1 (%)	R^2=1.00
Ejection fraction	2.3±1.9 (%)	4.0±3.3 (%)	R^2=0.98
Myocardial mass	11.6±8.7 (mL)	4.3±2.8 (mL)	R^2=0.98

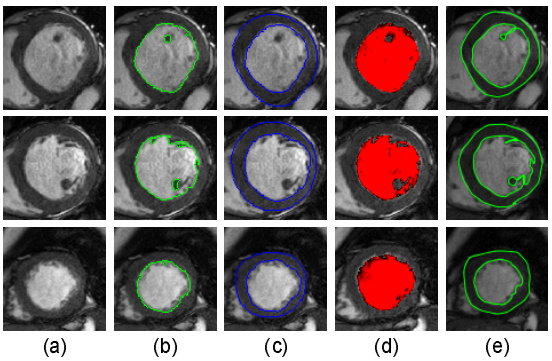

Fig. 2. Results. (a) image, (b) left ventricle, (c) myocardium, (d) partial volume image, (f) manual contour tracing