EPICARDIAL CONTOUR EXTRACTION BY LV-METRIC AND ACTIVE CONTOUR MODEL USING CARDIAC MRI

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INTRODUCTION: Quantification of cardiac output and myocardial mass in clinical practice are performed typically by manual tracing, which is a labor-intensive and time consuming process and dependant on inter- and intra-observer variability. The alternative is to segment ventricular blood and wall automatically using existing software, which fails to accurately trace the heart in most cases. In this study, we develop an automatic left ventricle (LV) segmentation algorithm to segment short-axis cine cardiac MRI. To segment LV and detect endocardial contour, we compensate the coil sensitivity of magnitude images and apply region-growing scheme, termed LV-METRIC. To detect epicardial contour and segment myocardium, we generate a circular map by polar mapping, extract edge information, and filter edge information using segmented LV. After defining the external force with prior knowledge, we apply guided active contour model to find epicardial contour, where initial contour is the endocardial contour from LV and only moves to radius direction on the circular map.

ALGORITHM

Endocardial contour extraction by LV-METRIC: We have developed a robust LV segmentation algorithm, termed LV-METRIC (Left Ventricular Myocardial Effusion Threshold Reduction with Intravoxel Computation) to automatically measure the blood volume of the LV [1]. LV-METRIC accounts for papillary and trabecular muscles through partial voxel interpolation. No prior shape information is assumed, except that the blood pool is enclosed by myocardium and the valves. It just requires minimal interaction at basal slices where the full circumference of myocardium may not be well imaged. LV-METRIC is performed in following steps: (1) estimate the initial seed point, (2) measure mean and standard deviation of blood signal, (3) compensate for coil sensitivity, (4) estimate myocardium signal intensity, and (5) segment LV by region-growing scheme and measure blood volume.

Epicardial contour extraction by ACM: Active contour model (ACM) extract the targeted object by iteratively minimizing energy composed of internal energy and external energy. The standard ACM algorithm may fail to converge to the object if the initial contour locates far from objects, causing it difficult to define the external force. We solve this problem for LV segmentation by introducing an external force based on image intensity and gradient information. Our epicardial contour ACM extraction algorithm consists of the following steps (refer Fig. 1): (1) generate circular map by polar mapping whose center is center of gravity in LV, (2) extract edge and filter out the edge from LV, (3) define external force using image gradient and constrain the contour move within an approximate region of myocardial signal estimated by LV-METRIC, (4) apply ACM at endocardial contour from LV, and (5) update epicardial contour by low-pass filtering and transform coordinate in image domain. To design the external force, we replace gradients whose values are smaller than pre-defined threshold with the nearest-right above-threshold gradient value. Since the intensity statistics of LV and myocardium is estimated from LV-METRIC, this information is used as constraint on the contour movement during energy minimization.

MATERIALS AND METHODS: Cardiac cine SSFP scans were performed on 20 patients and 18 volunteers with a GE Signa 1.5T scanner. A mean age of volunteers was 48 years with range from 25 to 77. A mean age of patients was 57 years with range from 14 to 77. Total 339 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.

Table 1. Comparison with manual contouring

	Volume	Manual contouring – Our segmentation		
		Absolute	Relative	Corr.
Patient	Blood	-4.9±3.1 (mL)	-3.7±2.6 (%)	R^2=0.99
	myocardium	6.9±6.6 (mL)	2.5±2.4 (%)	R^2=0.99
Volunteer	Blood	-5.0±3.7 (mL)	-3.8±2.4 (%)	R^2=0.98
	myocardium	4.0±3.1 (mL)	1.7±1.2 (%)	R^2=0.99

RESULTS: We measured blood volume of LV and epicardial volume in diastolic phase using our segmentation and compared with manual contour tracing. Table 1 summarizes blood volume and epicardial volume of the 20 patients and 18 volunteers in diastolic phase. In case of manual contour tracing, we know a kind of over-segmentation results. Also, it has difficulty to segment the fine details of complex cardiac structures. Fig. 2 shows magnitude images, LV by LV-METRIC, myocardium by ACM, and manual contouring. 34 cases are fully automated without user intervention. However, 4 cases (5 images) require a small amount of user intervention in apical slices.

DISCUSSION: Our ACM algorithm constrained with knowledge of blood and myocardial signal statistics estimated in the segmentation of endocardium (by LV-METRIC) allows highly automated segmentation of epicardium. The myocardial mass estimated automatically correlates well with that by manual tracing. In a very small fraction of image slices where the intensity difference between myocardium and its surrounding tissue is small, the ACM detected epiocardial contour may extend beyond myocardium, causing errors in the measurement of ventricular wall mass. The algorithmic error defined by the difference from manual contouring is smaller than the operator variability in manual contour tracing (~21.3 mL). Further improvement may reduce or eliminate this error.

REFERENCES: [1] N. C. F. Codella, et al, Radiology, 2007 (in revision).

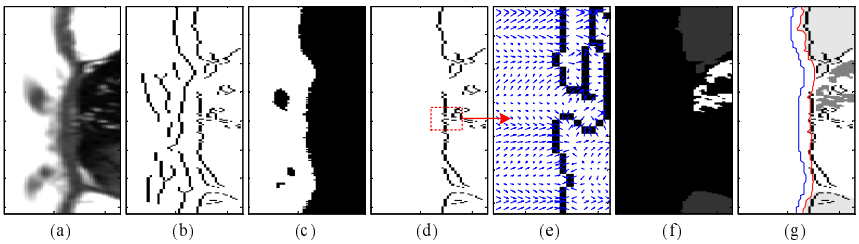

Fig. 1. Epicardial contour extraction by ACM. (a) circular map, (b) edge, (c) LV from LV-METRIC, (d) filtered edge, (e) external force, (f) constraint, (g) initial contour (in blue) and extracted epicardial contour (in red).

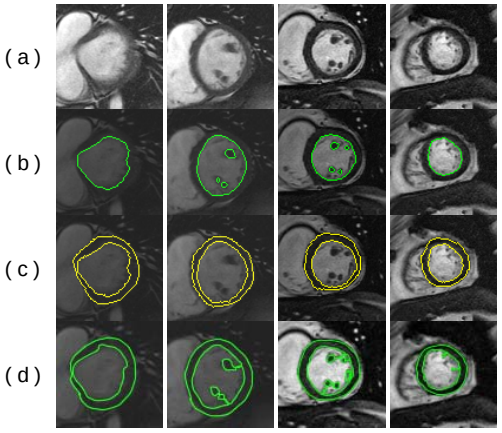

Fig. 2. Segmentation results. (a) image, (b) left ventricle, (c) myocardium, (d) manual tracing