Accuracy of Automatic Contour Detection for Quantification of Left Ventricular Volumes, Mass and Ejection Fraction

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Introduction: Determination of left ventricular (LV) volumes and ejection fraction (EF) from short-axis (SA) cine CMR images requires accurate delineation of myocardial contours, a process which is time consuming when performed manually. Furthermore, it is typical to identify contours only at two cardiac phases, i.e. end-diastole (ED) and end-systole (ES), due to the tedium of hand-tracing contours. Automatic contour detection methods offer the potential for reduction in analysis time while also delineating contours across all cardiac phases. Both manual and automated methods must account for through-plane motion due to the base-to-apex contraction of the functioning heart, i.e. the number of slices encompassing the left ventricle varies with cardiac phase, with more basal slices present at ED versus ES.

Purpose: In this work we examine cine CMR data derived from a large, community-based cohort to determine: 1) the contribution of the basal LV slice(s) at ED to LV volumes and EF and 2) the effect of manual correction of automatically-detected LV contours on global LV functional parameters.

Methods: Cine CMR imaging was performed on 1555 participants of the Framingham Heart Study Offspring cohort using an ECG-gated SSFP cine sequence. A contiguous short-axis stack of 10-mm thick 2D slices (TR = 3.2ms, TE = 1.6ms, flip angle = 60, FOV: 400mm, temporal resolution 30-40ms) was obtained covering the entire left ventricle. The image data were analyzed using a strict, 3-step protocol. Step 1: automatic contour detection was applied *only* to the slices showing a complete ring of LV myocardium at *all phases*. Step 2: additional (principally basal) slices at end diastole were delineated manually; these slices did not contain LV myocardium at ES, due to cardiac base-to-apex shortening and hence were not submitted for automated detection. Step 3: detailed corrections to the automatically-detected myocardial contours from Step 1 were performed. Functional parameters were quantified at each step.

Results: Automatic contour detection (Step 1) was performed at 8148 slices and successfully located the LV myocardium in 8072 slices (99% success rate). Out of 323,202 contours, 16,378 contours (5%) were modified manually. The median ± interquartile range analysis time was 7.6 ± 1.7 minutes, which included 4.9 ± 1.6 minutes for reviewing and correcting the automatic contours. The volumetric difference between the final (Step 3) functional parameters versus Step 1 (initial automated) and Step 2 (manual addition of basal ED contours) are listed in Table 1. Figure 1 shows scatter plots of the EF at Step 1 (left panel) and at Step 2 (right) versus the final Step 3 EF.

	Step 1 vs. Step 3	Step 2 vs. Step 3
ED Volume (ml)	(-43.0 ± 18.1) 0.71	(0.4 ± 4.1) 0.98
ES Volume (ml)	(-0.1 ± 5.5) 0.88	(-0.3 ± 2.9) 0.97
Stroke Volume (ml)	(-42.9 ± 17.0) 0.43	(0.7 ± 3.1) 0.98
EF (%)	(-13.3 ± 5.1) 0.60	(0.3 ± 1.8) 0.93
CO (l/min)	(-2.7 ± 1.1) 0.46	(0.0 ± 0.2) 0.98
LV Mass (g)	(-27.2 ± 14.1) 0.79	(0.3 ± 6.8) 0.96

Table 1: Difference of volumetric parameters (mean ± SD) R^2 derived after Step 1 and Step3, and after Step 2 and Step 3. CO = cardiac output; EF = ejection fraction.

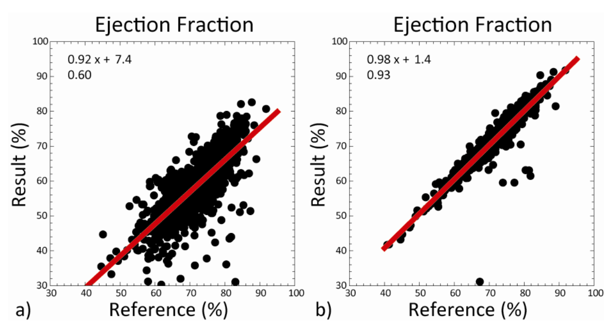

Figure 1: Scatter plots of the LV ejection fraction after Step 1 vs. after Step 3 (a), and after Step 2 vs. after Step 3 (b).

Conclusions: Automatic myocardial contour detection for determination of LV volumes and EF is feasible and time efficient in a large, population-based sample of adults. After inclusion of basal slice data, further manual corrections to the automatically-detected contours have minimal effect on the final outcome of global functional parameters.