A GEOMETRIC METHOD BASED ON MASS CENTER DRIFTING DETECTION FOR IMPROVING BASAL LEFT VENTRICLE AUTOMATED SEGMENTATION

M. Pei[1], L. Wang[1,2], J. Li[1], M. Fan[1], and Y. Wang[2,3]

[1]Shanghai Key laboratory of Magnetic Resonance, East China Normal University, Shanghai, Shanghai, China, People's Republic of, [2]Department of Radiology, Weill Medical College of Cornell University, New York, NY, United States, [3]Department of Physiology, Biophysics, and Systems Biology, Weill Medical College of Cornell Universi, New York, NY, United States

INTRODUCTION: Automated left ventricle segmentation is very useful for reading cardiac MRI. It is known from priori LV segmentation investigations [1-4] that basal ventricle segmentation is difficult due to its complex anatomy compared to mid-ventricle and apical-ventricle. To improve accuracy and robustness of automated left ventricle segmentation on short-axis cardiac MRI, a novel geometric method is proposed to define effusion of segmented area on basal cardiac ventricle slices for correct automated segmentation.

ALGORITHM: 1) To roughly locate the left ventricle, Hough transform[5-6] is performed on the subtraction of images from end-diastolic phase and end-systolic phase in mid-ventricle. 2) Automated segmentation using an iterative threshold region growth algorithm[4] is performed from mid-ventricle slices to apical-ventricle slices. 3) the coordinates of mass center ($[X_c, Y_c]_{s,p}$) of the segmented area are extracted for each slice and each cardiac phase and are linearly regressed over all slices for each phase. 4) Automated segmentation is continued towards the basal slice. 5) Erroneous effusion from LV in segmentation is corrected in the following manner: (a) compute the mean coordinates $[X_{c\,I}, Y_{c\,I}]$ of the subtraction of segmented areas from current slice and intermediately previous slice; (b) compute the coordinates $[X_{c\,II}, Y_{c\,II}]$ according to Eq.1by searching the edges in 4 directions voxel by voxel, where N is the total number of voxels in the subtraction of segmented areaes, $(x_{edge-})_i$, $(x_{edge+})_i$, $(y_{edge-})_i$, $(y_{edge+})_i$ are x or y coordinates of nearest edge of 4 directions (x-,x+,y-,and y+) for any voxel i in the subtraction of segmented areas, (c) the segmentation area in the current slice is set to that of the immediately previous slice when both coordinates $[X_{c\,I}, Y_{c\,I}]$ and $[X_{c\,II}, Y_{c\,II}]$ are beyond a distance threshold (2.5 std dev away from the mass center linear regression) from $[X_c, Y_c]_{s,p}$ for a given slice and phase.

$$X_{c\,II} = \frac{1}{N}\sum_{i=0}^{N}[(x_{edge-})_i + (x_{edge+})_i]/2$$
$$Y_{c\,II} = \frac{1}{N}\sum_{i=0}^{N}[(y_{edge-})_i + (y_{edge+})_i]/2 \qquad \text{(Eq.1)}$$

MATERIALS AND METHODS: This study was approved by our IRB. Cine cardiac MRI data from 30 subjects (23 male, mean age 48.4 years ±16.8 SD) were analyzed. All the cine 2D SSFP cardiac images were acquired using a GE 1.5T scanner, imaging parameters as follows: TR 3.3-4.5 ms, TE 1.1-2.0 ms, flip angle 55-60, matrix size 192×192 – 256×256, image dimensions 256×256, receiver bandwidth 125 kHz, FOV 290-400 × 240-360, slice thickness and slice gap 6-8 mm and 2-4 mm, respectively(total 10 mm). The LV in each case was imaged in 10 -15 slices, 20-28 cardiac phases. Automated LV segmentation algorithm with this method was used to measure left basal ventricle volumes, left ventricle volumes and LVEF, and compared with expert manual tracing.

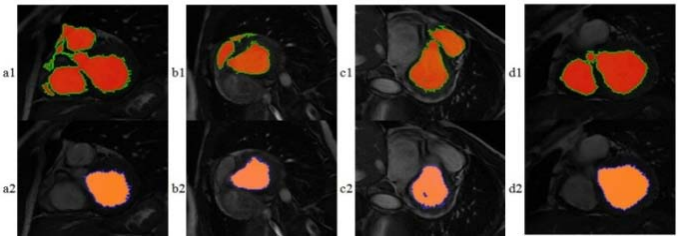

Figure 1: Example of incorrect segmentation on basal ventricle slices (a1-d1) in comparison of corrected segmentation (a2-d2) with presented method for defining effusion and region constraints methods.

RESULTS: The success rate for correctly identifying erroneous effusion at basal ventricle slices was 100.0%: 543/543 basal slices at all cardiac phases for all 30 patients. The success rate of correcting erroneous effusion was 89.9%: 488/543. Failure in correcting erroneous effusion was due to improperly assign segmented area to slice without sufficient myocardium.

Examples of successfully segmenting left basal ventricle images are illustrated in Figure 1. The comparison of automated measurements to manual tracing is shown in Table 1.

DISCUSSION: This geometric method is effective to detect the erroneous effusion area in automated segmentation of basal slices. It has a limited success in correcting the erroneous effusion, which may be further improved by estimating the percentage of myocardium [7]. This approach is promising for fully automated accurate segmentation of the left ventricle blood.

Difference in Left Basal Slice Volume between AM and MT		Difference in Left Ventricle Volume between AM and MT		
End-Diastolic Volume	**End-Systolic Volume**	**End-Diastolic Volume**	**End-Systolic Volume**	**Ejection Fraction**
0.15 ± 1.04 (mL) (y = 0.9455x + 1.4549, R^2 = 0.957)	0.73 ± 1.18 (mL) (y = 0.929 + 1.7398, R^2 = 0.904)	5.0 ± 9.7 (mL) (y = 1.056x - 5.245, R^2 = 0.978)	2.6 ± 9.9 (mL) (y = 0.986x + 3.577, R^2 = 0.952)	0.3 ± 2.7 (%) (y = 1.022x - 1.083, R^2 = 0.946)

Table 1: Results of Comparison of Automated Measurements (AM) to Manual Tracing (MT). All subtraction values shown are the average and standard deviation of paired difference (MT minus AM).

* x = MT, y = AM; ** No difference, except end-diastolic volume, are statistically significant (p > 0.05).

References:[1] Waiter, G.D., et al., Magnetic Resonance Imaging, 1999. **17**(1): p. 99-107. [2] Lynch, M., O. Ghita, and R.F. Whelan, Computerized Medical Imaging and Graphics, 2006. **30**(4): p. 255-262. [3] Hae-Yeoun Lee, et al., Journal of Magnetic Resonance Imaging, 2008; 28:1393-1401. [4] Codella, N.C., et al., Radiology, 2008. **248**(3): p.1004-12. [5] van der Geest, R.J., et al., Journal of Cardiovascular Magnetic Resonance, 2004. **6**(3): p. 609-617. [6] Illingworth, J. and J. Kittler, Computer Vision Graphics and Image Processing, 1988. **44**(1): p. 87-116. [7] Papavassiliu, T., et al., Radiology, 2005. **236**(1): p. 57-64.