Simultaneous Left and Right Ventricle Segmentation using Topology Preserving Level Sets

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INTRODUCTION: Cardiac performance is typically assessed measuring the ventricular volumes using Simpson's rule over Short Axis (SA) cine MRI scans. In Congenital Heart Diseases (CHD), biventricular function evaluation is crucial to determine the need of additional surgical interventions. These evaluations typically require a manual segmentation process. In this process, an expert has to draw the left and right ventricle endocardium contours on each slice of the anatomical volume, for two time frames. Finally, End Systole Volume (ESV) and End Diastole (EDV) can be calculated, and also Stroke Volume (SV) and other functional measurements. A more automatic process is needed to segment left and right ventricles.

PURPOSE: We propose a semi-automated approach, that combines Level Set segmentation [1] and a preserving topology algorithm [2], which allows to simultaneously segment left (LV) and right (RV) ventricles accurately and reducing computation time, compared with manual segmentation. The preserving topology algorithm keeps constant the number of objects initialized during the Level Set segmentation process, avoiding merging, splitting or hole appearing. We assume that papillary muscles needs to be excluded.

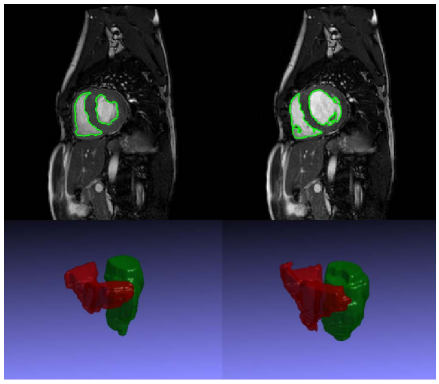

Figure 1: Bland Altman analysis of manual segmentation and our proposed method. Graphics a)- d) show the ESV, EDV for left and right

METHODS: Simultaneous RV and LV segmentation were performed using 2D Chan-Vese (CV) [1] algorithm (Level Set-based) and the preserving topology algorithm presented in [2]. User interaction needed consist of identifying systole and diastole frames from an MRI cine sequence and then four clicks specifying the base and apex slices of both, LV and RV. The first slice is initialized with 3 by 3 pixel circles in the selected point, and then the contour is propagated slice by slice, from the apex to the base. Minor manual corrections are often needed at the basal slice. The segmentation parameters were: $\mu = 0.02 \times 255^2$; $\lambda_1 = 1$; $\lambda_2 = 0$; $\Delta t = 0.0005$; and stopping condition 200 iterations. The topology preservation parameters were: foreground connectivity = 8 and background connectivity = 4.
For our method validation, we segmented b-SSFP cine MRI scans with different cardiac diseases, acquired on Philips 1.5T with the following imaging parameters: acquisition matrix 256x256x12, spatial resolution 1.6mm^2; slice thickness 8mm; TR/TE = 3/1 ms, and temporal resolution 30ms. We compared our method with 15 segmentations performed with Segment software [3]. In order to measure the accuracy of our method DICE index was calculated, which is defined as:

$$DICE = 2\frac{S_{manual} \cap S_{method}}{S_{manual} + S_{method}}$$

;
and also functional indexes End Systolic Volume (ESV), End Diastolic Volume (EDV) and Stroke Volume (SV) were evaluated, which are standard indexes in clinical practice. These results were statistically analyzed using Bland Altman.

RESULTS: Literature stablished that a reasonable DICE value is >0.7 [4]. Table 1 shows the results obtained by comparison between our method and manual segmentation. All the indexes were above 0.9, but more accurate results were observed in LV compared with RV. That was because RV has a complex shape and internal structures, with high variability in trabeculations, compared with LV papillary muscles.

Table 1: DICE results

DICE	ESV	EDV
LV	0.93 ± 0.020	0.94 ± 0.017
RV	0.90 ± 0.022	0.92 ± 0.020

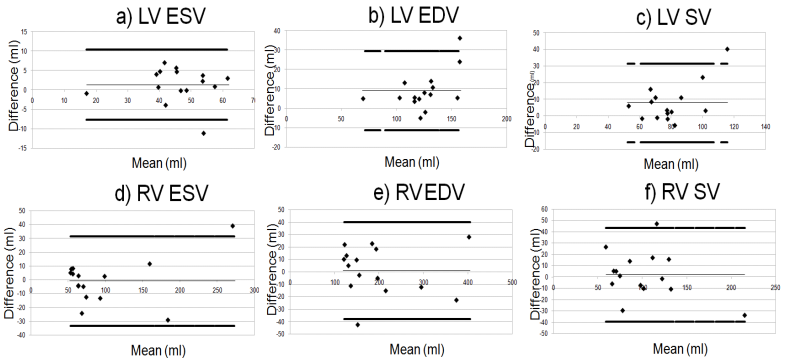

Figure 2: Bland Altman analysis

Bland Altman analysis showed (Figure 2) that the ESV, EDV and VS obtained with our method were equivalent to those computed with manual segmentation. The whole segmentation processing time for each patient was approximately seven minutes and extra ten minutes when manual corrections are needed, whereas manual segmentation took approximately 40 minutes.

CONCLUSIONS: The statical analysis showed that our proposed method have an excellent agreement with manual segmentations. The main advantages of our method are that we reduced the processing time, our method allows segmenting simultaneously LV and RV. This makes it particularly useful in abnormally shaped hearts.

REFERENCES: [1] T.F. Chan, L.A.Vese. IEEE TIP 10(2), 2001. [2] X. Han, C. Xu, J.L. Prince, IEEE TPAMI, 25 (6), 2003. [3] E. Heiberg, et al., BMC Medical Imaging, 10(1), 2010. [4] Pluempitiwiriyawej, C., et al., IEEE TMI, 24(5), 2005.
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