Fully automatic segmentation of the left ventricle in cardiac cine MR images

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Introduction: Assessment of global left ventricular function is typically performed by delineation of endocardial contours on a stack of short-axis cine magnetic resonance (MR) images that cover the left ventricle from base to apex. Given the time-consuming nature of manual or semi-automatic contour delineation, only the end-diastolic and end-systolic phases are typically segmented in clinical routine. This approach however is operator-dependent and does not fully exploit the image information available. In this work we sought to evaluate the feasibility of fully automatic segmentation of cine short axis images of the left ventricle. The method developed performs segmentation across all cine phases and slices during image reconstruction, allowing for immediate measurement of the ventricular-volume time course and subsequent determination of the end-diastolic (ED) and end-systolic (ES) volumes and the ejection fraction during image acquisition. No user interaction is required.

Methods: *Algorithm:* The segmentation algorithm combines edge, region and shape information to automatically localize and then delineate the myocardial boundaries [1]. In order to allow for fully automatic segmentation, the following assumptions were made: a) a series of contiguous short axis slices is acquired covering the entire left ventricle from base to apex. This is due to the distinct shape and form of the left ventricular cavity near the base which facilitates automatic localization. b) The ED and ES phases are the phases with the largest and smallest cavity areas, respectively. c) The most basal slice at ED is positioned perfectly through the most basal part of the left ventricle. d) The most basal slice at ES is one slice below that at ED. The steps involved in the unsupervised segmentation algorithm are as follows: 1) once the second most basal slice has been acquired, the left ventricle is automatically localised and segmented in all cardiac phases. The first phase of this slice serves as a template for contour propagation to immediately adjacent slices. 2) Once the template image has been segmented, contours are propagated to the previous slice and results displayed within 10-15 seconds after completion of the slice acquisition. 3) The segmentation of all following slices is performed immediately after slice acquisition i.e. slices are acquired, image segmentation is performed and segmented images are displayed. Once the entire stack of short-axis slices has been acquired, the ED and ES volumes and the ejection fraction are determined. *MR imaging:* A total of 20 subjects (8 healthy volunteers and 12 patients) were imaged on a 1.5 T Siemens Avanto a Tim system using two six-channel matrix surface coils. Following localisation, a stack of 10-12 cine TrueFISP images (TR/TE/flip angle: 2.9 ms/1.2 ms/65 deg; temporal resolution 42 ms; spatial resolution 1.33 mm x 1.33 mm x 8 mm) covering the entire left ventricle were acquired using a triggered retrogating technique and vector-cardiographic triggering during suspended respiration.

Results: Representative segmented short axis images are shown in Figure 1. The same data was analysed offline using a combination of manual and semi-automatic tracing techniques in a commercially-available software package, Argus (Siemens Medical Solutions, Germany). A Bland-Altman plot comparing the ejection fraction results obtained using the fully-automatic and the manual approaches is shown in Figure 2. The mean difference for the ejection fraction was 0.76 % (standard deviation of the differences, SD = 3.91 %), for the end diastolic volume -8.29 ml (SD = 10.38 ml) and for the end systolic volume -5.05 ml (SD = 8.32 ml).

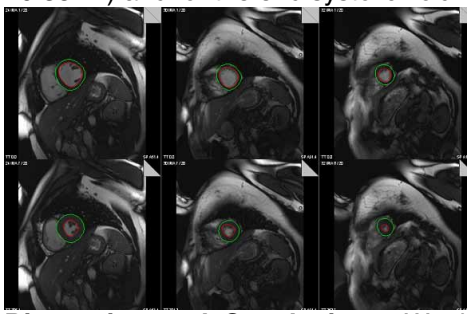

Figure 1. Automatically segmented images of the left ventricle at end-diastole (top row) and at end systole (bottom row).

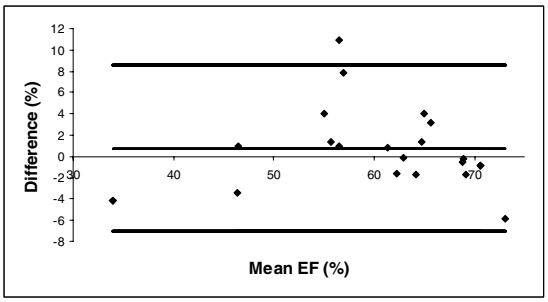

Figure 2. Bland-Altman plot showing the difference against the mean for the fully-automatic and manual analyses of the ejection fraction.

Discussion and Conclusions: We have demonstrated the feasibility of fully-automatic segmentation of the left ventricle. The differences between the automatically determined values describing global cardiac function and those determined using manual and semi-automatic techniques are in close agreement with values for inter- and intra-observer and inter-study variability reported in the literature (see [2] and references cited therein, for example). The method, which is executed during image acquisition, provides a rapid estimate of the ED and ES volumes and the ejection fraction. Moreover, it also allows for a complete description of the entire volume-time curve and hence extraction of parameters related to the magnitude and velocity of volume changes during the processes of ejection and filling. The evaluation of such parameters will be the subject of further research.

References:

[1] Jolly, M-P., Combining edge, region, and shape information to segment the left ventricle in cardiac MR images. Proc. MICCAI, Utrecht, The Netherlands, pp482-490, 2001.

[2] Hudsmith, L.E. et al., Normal human left and right ventricular and left atrial dimensions using steady state free precession magnetic resonance imaging. J. Cardiovasc. Magn. Reson., 7 (2005) pp775-782.