FAST FREE-BREATHING CARDIAC FUNCTION ASSESSMENT WITH AUTOMATED SEGMENTATION USING MOTION-CORRECTED 2D MULTI-SLICE SSFP

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Target audience MR scientists and clinicians interested in cardiac function assessment, and cardiac MRI.

Introduction Conventionally cardiac function assessment is performed by cine MRI with whole heart coverage using a stack of ECG-gated 2D SSFP sequences. To cover the left ventricle (LV), 12 to 14 slices need to be acquired in successive breath-holds which typically requires 6 to 10 min depending on patient cooperation. The post-processing is also time-consuming due to the need for segmenting the LV cavity in all slices in diastole and systole. In this work, we propose an optimized cardiac function acquisition and post-processing using a combination of: i) a free-breathing, 2D multi-slice SSFP sequence with 3D GRICS motion correction [1] (no scanner idle time, 4-5 min total acquisition time); ii) a semi-automatic segmentation technique based on geometrically constrained fuzzy c-means. We demonstrated the efficacy and robustness of this approach in 5 Duchenne muscular dystrophy (DMD) patients with great difficulty with holding their breath.

Methods 5 DMD patients (4 children and 1 adult, 10-20 years old, heart rate 108 (±12)) were scanned on a 1.5 T GE Signa scanner, using an 8-element cardiac coil, with ethic approval. A short-axis 2D cine SSFP sequence with no slice gaps was exploited first to cover the whole heart (10-12 slices in total depending on patients), with TE/TR 1.8/4.0 ms, acquisition matrix 224x224, in-plane resolution 1.25x1.25 mm^2, slice thickness 8 mm. The cardiac and breathing motion were compensated by a reconstruction method, GRICS [1]. A phase-contrast cine (PC-cine) sequence was also applied in order to provide a reference of the stroke volume (SV) measurements as no valvular leak was reported for all the patients. The LV function parameters, end-diastolic/end-systolic volume (EDV/ESV), stroke volume (SV) and ejection fraction (EF), were assessed based on the 2D cine data.

A semi-automatic segmentation algorithm (with minimal user interaction, 2 points to locate heart position and 1 point for cavity position in the central slices) using geometrically constrained fuzzy c-means clustering was developed and implemented in MATLAB to delineate the endocardium contour of the LV for the functional parameter calculation. The quality of endocardium segmentation was evaluated by comparing with manual segmentation. The resulting functional parameters were validated by using the stroke volume calculated from PC-cine data using freely available software SEGMENT [2] as a reference and assessed statistically using Bland-Altman analysis. All results are expressed as mean (±1.96SD).

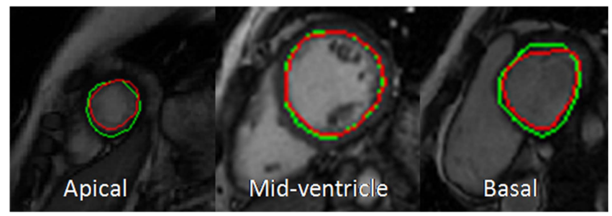

Fig 1. Acquisition and segmentation examples of 2D multi-slice cine data (red is manual segmentation contour, green is automatic segmentation contour).

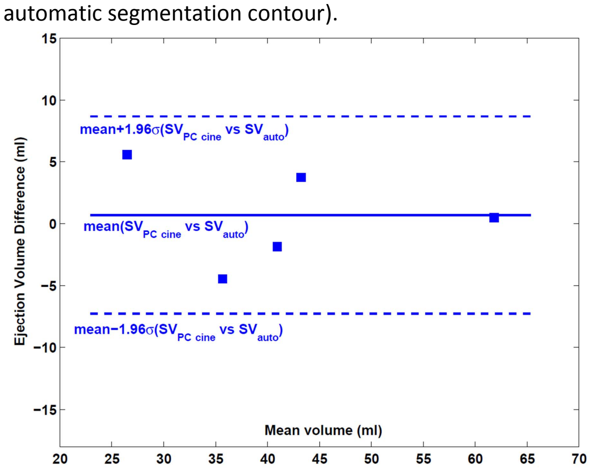

Fig 2. Bland-Altman plot for assessment between $SV_{PC\text{-}cine}$ and SV_{auto}

Results Including pre-scan, the average acquisition time of the multi-slice cine is 5min 2s (±44s). The image quality was assessed by 2 experienced radiologists and was considered to be of diagnostic quality (Fig 1). The segmentation result example is shown in Fig 1 (red for manual segmentation, green for the proposed semi-automatic segmentation). The mean differences between functional parameters extracted from manual and semi-automatic segmentation were: 3.1(±6.2)ml for EDV, 1.5 (±8.6)ml for ESV, and 5.4(±8.7)ml for SV. The agreement between $SV_{PC\text{-}cine}$ and SV_{auto} is presented using Bland-Altman plot (Fig 2, mean difference 0.7±8.0 ml). The average functional parameters of all the patients were $SV_{PC\text{-}cine}$ = 42.0 (±25.6) ml, SV_{auto} = 41.3(±27.2) ml and EF_{auto} = 52.7(±15.6)% .

Conclusion We demonstrated the feasibility of achieving full cardiac coverage MR functional assessment within a much shorter time without losing spatial and temporal resolution on 5 patients with one of the most difficult-to-manage cardiac disease for CMR exam. The acquisition allows a semi-automatic robust LV functional assessment with minimal user interaction. This method can potentially be used for routinely cardiac examination, especially for patients with breathing difficulties or uncooperative patients, e.g. children.

Reference: [1]. Odille et al. MRMI vol 60(1) pp 146-57, 2008. [2]. http://segment.heiberg.se