AN EFFICIENT ALGORITHM FOR VOLUMETRIC MEASUREMENT OF LEFT VENTRICLE USING REAL TIME CINES

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Introduction Free-breathing real-time cine is a robust way to study ventricular function of cardiac patients since it does not require breath-hold and is immune to arrhythmia. However, volumetric quantification is not easy as the heart moves throughout the acquisition period due to respiration. The most common way is to visually inspect cines frame by frame to identify images at end-expiratory phases[1, 2]. Such laborious and time-consuming method greatly hinders its clinical applications. Alternatively, respiratory motion could be corrected by registering images over multiple cardiac phases[3, 4], but it increases both acquisition time (>30 s) and SAR and may not be favorable at high field. In this study, we propose an efficient approach to identify end-diastolic (ED) and end-systolic (ES) phases of real time cines at end-expiration needed for ventricular measurements without going through all the images. Its feasibility and accuracy was compared to the standard segmented breath-held cines.

Materials and Method The algorithm: The analysis starts from the first cine image of each slice. A reference point was manually placed inside the left ventricular (LV) cavity. Using it as the center an ROI covering the short-axis LV was automatically selected (Fig. 1a). Two-level K-means cluster segmentation[5] was applied to the ROI to differentiate blood pool from myocardium (Fig. 1b). The endocardial contour was fit to an ellipse with its center as the LV centroid (Fig. 1c). The steps were repeated for other phases with the current LV centroid propagated to the next phase as its reference point. The displacement of LV centroid along the superior-inferior direction over time represents mixed respiratory and cardiac motions of that slice over the imaging period. Respiratory signal (~0.1-0.5 Hz[6]) was extracted by applying a low-pass filter with cut-off frequency of ≈ 0.8 Hz to remove cardiac signal (typically frequency range > 1.0 Hz for adult). End-expiratory phase was identified when the averaged centroid position within a cardiac cycle located most superior (Fig. 2). ED and ES images, exhibiting the least correlation coefficients among the images at end-expiratory phase, were the ones with the largest and smallest fitted ellipse areas respectively.

Experiment: A 3T MR scanner (TIM TRIO, Siemens, Germany) was used. The IRB approved study scanned 12 healthy volunteers (age 27±3, with informed consent). After localizing the imaging planes for the short-axis views, cines of ten short-axis slices covering the whole heart from base to apex were acquired with a standard retrogated breath-held SSFP cine, followed by free-breathing real-time SSFP techniques. Imaging parameters were: slice thickness = 8mm with 2mm gap, FOV = 340×287mm^2. For the standard cine protocol: TR/TE = 3.4/1.5ms, matrix size = 256×216, iPAT = 2, bandwidth = 977 Hz/pixel, 12 segments. For the real-time cine protocol: TR/TE = 2.5/1.1ms, matrix size = 160×96, TPAT = 4, bandwidth = 1488 Hz/pixel, temporal resolution = 59.5ms, scan time per slice = 5s to include at least a complete respiratory cycle. A KLT filter was applied along temporal direction to increase SNR[7].

Analysis: LV volumes were found from the standard cine in the usual way. For real time cines, identified ED and ES images at end-expiration were imported to QMass MR (Medis, Netherland) for LV function analysis. LV myocardial mass (MM), ED volume (EDV), ES volume (ESV) and ejection fraction (EF) were analyzed with papillary muscles excluded from myocardium. Linear correlation analysis was performed to obtain the correlation coefficient (r) between paired measurements. Two-tailed paired t-test was conducted with $p<0.05$ regarded as statistically significant.

Fig. 1 LV centroid identification.

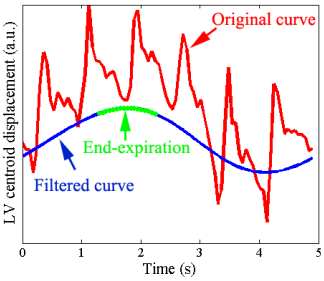

Fig. 2 LV centroid displacement.

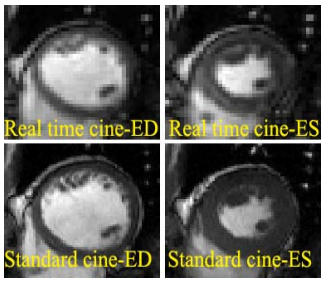

Fig. 3 ED and ES images.

Results Identified images with the proposed methods were largely the same with those determined by visual inspection. Fig. 3 shows the ED and ES images of a typical slice obtained from standard and real-time cine protocols. Table 1 summarizes the quantitative results. MM, EDV, ESV, SV and EF measured from the two protocols were found to be very close and correlated very well with each other, although statistical significant differences presented for some LV function parameters.

Discussion and conclusion Using real time cine together with the proposed method, the LV function measurements compared favorably with the standard methods of finding LV function. The results demonstrated that the proposed method can correctly identify ES/ED phases from real time free-breathing cine; and real time cine can be reliably used for LV function quantification despite its lower spatial and temporal resolution. The proposed image processing approach would greatly facilitate clinical adoption of real-time cine technique for LV function assessment. Clinical studies would be needed to fully validate this method.

Table 1 LV function measured from the two cine protocols.

	MM (g)	EDV (ml)	ESV (ml)	SV (ml)	EF (%)
Real time cine	87.2±16.4	124.5±17.8	48.3±8.6	76.2±11.7	61.2±4.0
Standard cine	89.6±16.4	125.0±17.1	49.9±9.1	75.2±10.3	60.2±3.8
r	0.99	0.99	0.99	0.96	0.92
p value	0.01	0.53	0.004	0.26	0.04

References [1] Francone et al, JMRI 2005; [2] Kaji et al, JACC 2001; [3] Kellman et al, MRM 2008; [4] Hansen et al, MRM 2011; [5] Hartigan et al, Applied Statistics 1979; [6] Buehrer et al, MRM 2008; [7] Ding et al, PMB 2009. **Acknowledgments** GIRTF-LCHT, BRPSZ JC201005270311A.