AN EFFICIENT APPROACH FOR ANALYSIS OF REAL-TIME CINE FOR LV FUNCTION QUANTIFICATION

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Introduction Real-time free breathing cine imaging is highly desirable in evaluating ventricular functions of cardiac patients, especially for pediatric patients and those who suffer from arrhythmia or respiratory failure. However, volumetric measurement of ventricular functions with free breathing real-time cine is not easy. The spatial position of the ventricle changes over the multiple heart beats, and thoracic positions of multiple slices in the cines may be mismatched to each other due to respiratory motion, leading to errors in volumetric quantification. Images over multiple phases may be registered before volumetric measurements [1] but it increases both acquisition time and SAR and may not be favorable at high field. More commonly, cine images are visually inspected frame by frame to identify cardiac cycles at end-expiration for ventricular measurements [2] and is both laborious and time consuming. In this study, we propose a simple but effective approach to identify end-diastolic (ED) and end-systolic (ES) phases at end-expiration graphically from real-time free breathing cines without going through all the cine images. Its use and accuracy in ventricular measurements was compared to the standard segmented breath-hold SSFP cines acquired at 3T.

Materials and Method When a reference line is put across the short axis of the left ventricle, the signal along the line changes with time on a cine. Respiratory motion can be observed at the point where the line crosses the chest wall and the liver/diaphragm, Cardiac motion can be derived from the blood/myocardial border. These two signal changes along the time axis therefore can help depict the expiratory phase of respiration, and the cardiac cycle. Based on this fact, a MATLAB program was developed to plot the signal profile along the reference line for all acquired cardiac frames (Fig.1) from which ED and ES phases at end expiration were identified. Experiment: A 3T MR scanner (TIM TRIO, Siemens, Germany) was used. The IRB approved study scanned eight healthy volunteers (age 26±3). 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 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, k-space lines/heart beat = 12, temporal resolution = 40.7ms. 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, cine duration of each slice was 5s to include end-expiratory and end-inspiratory phases. A KLT filter was applied along temporal direction to increase SNR [3]. Analysis: ED and ES images at end-expiration were semi-automatically identified with the developed program and imported to QMass MR (Medis, Netherland) for LV function analysis. LV myocardial mass, ED volume (EDV), ES volume (ESV) and ejection fraction (EF) were analyzed by two independent observers with papillary muscles included in LV chamber volume. Inter-observer variability (IOV), defined as (observation$_1$-observation$_2$)/mean of the two observations, were calculated. Linear correlation analysis was performed to obtain the correlation coefficient (r) between paired measurements averaged from the two observers. Two-tailed paired t-test was conducted to assess the statistical differences with p<0.05 regarded as statistically significant.

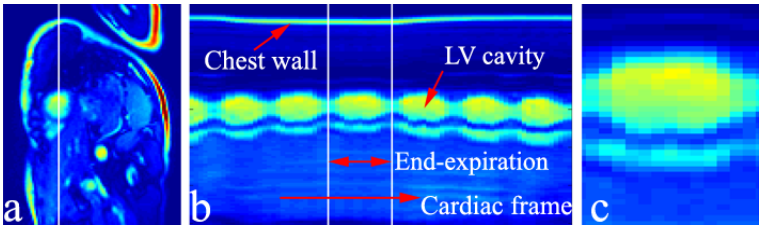

Fig 1 Cardiac cycles at end-expiration as zoomed in at (c).

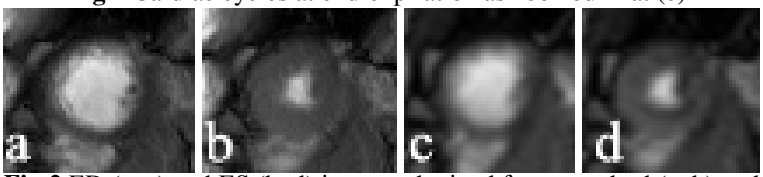

Fig 2 ED (a, c) and ES (b, d) images obtained from standard (a, b) and real-time (c, d) cine protocols.

Results Fig.2 shows ED and ES images of a representative slice obtained from standard and real-time cine protocols. Results from the analysis were summarized in Table 1. EDV, ESV, SV, EF, and myocardial mass measured from the two protocols correlated very well without any statistical significant differences. Inter-observer variability was small (<±5%) in both protocols, and was slightly lower in the real-time protocol than that of the standard one.

Table 1 LV function measured from the two SSFP cine protocols.

	Comparison of the two protocols				IOV (%)	
	Standard	Real-time	p-value	r	Standard	Real-time
EDV (ml)	120.8±11.7	119.2±11.0	0.23	0.96	1.3±1.3	1.1±1.0
ESV (ml)	47.1±7.4	47.1±7.6	0.94	0.97	-1.9±3.2	0.8±3.1
SV (ml)	73.6±5.9	72.1±5.2	0.14	0.92	3.1±3.5	1.2±2.0
EF (%)	61.1±3.2	60.7±3.5	0.37	0.95	1.8±2.5	0.2±1.8
Mass (g)	90.1±8.0	90.9±7.6	0.23	0.98	-0.8±2.5	-0.7±1.5

Discussion and conclusion LV function measured from the two methods are very similar, implying that: (1) the proposed method can correctly identify ES/ED phases from real time free breathing cine; and (2) despite the lower spatial and temporal resolution of real time free breathing cine, it is good enough for LV function assessment [4]. The technique here would greatly facilitate clinical adoption of real-time cine technique for LV function assessment. Clinical studies would be needed to fully validate this method.

References [1] Kellman et al, MRM 2008; [2] Beer et al, Int J Cardiol 2010; [3] Ding et al, PMB 2009; [4] Yamamuro et al, JCMR 2006.

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