A ROBUST AND FAST SSFP CINE FOR THE EVALUATION OF LV FUNCTION AT 3T

Yin Wu[1,2], Yinzhu Gao[1,2], Ke Jiang[1,2], Yucheng Chen[3], and Yiu-Cho Chung[1,2]

[1]*Paul C. Lauterbur Research Centre for Biomedical Imaging, Shenzhen Key Laboratory for MRI, Shenzhen Institutes of Advanced Technology, Shenzhen, Guangdong, China,* [2]*Key Laboratory of Health Informatics, Chinese Academy of Sciences, Shenzhen, Guangdong, China,* [3]*Cardiology Department, West China Hospital, Sichuan University, Chengdu, Sichuan, China*

Introduction 3T MRI is advantageous to CMR because it can offer higher SNR and better T1 contrast, However, its main field inhomogeneity often introduces banding artifacts in SSFP cine, which greatly slows down the clinical workflow due to the need for pre-scans (such as shimming, frequency scout, etc.) to avoid/reduce the artifact[1]. Wideband SSFP[2] has been proposed but it increases the SAR, and is less efficient than conventional SSFP. It is uncommonly on clinical scanners neither. Shortening TR is a simple way to reduce SSFP sequence's sensitivity to main field inhomogeneity, but would usually have reduced image spatial resolution, and such influence on LV function quantification is not yet known. In this study, we proposed a shorter TR SSFP cine protocol, and evaluated its accuracy in LV function measurement using a standard high resolution SSFP cine protocol as reference.

Method Protocol: The new protocol differs from a standard protocol in that: (1) a shorter RF pulse is used (600us versus 1000us); (2) a lower resolution matrix is adopted (192 versus 256) to shorten the readout time. Maximum bandwidth was used in both cases. TR/TE was reduced from 3.4/1.5ms to 2.7/1.2ms. At ~40ms temporal resolution and 85% phase FOV, the number of segmented k-space lines/heart beat increased from 12 to 15, shortening patient's breath-hold time by ~40%.

Imaging: A 3T MR scanner (TIM TRIO, Siemens, Germany) was used in the study. The IRB approved study scanned ten healthy volunteers (age 26±3) and six cardiac patients (age 50±12, 4 with premature ventricular beat and 2 with LV hypertrophy). Cines of ten short-axis slices covering the whole heart from base to apex were acquired with the two retrogated breath-held SSFP techniques. Imaging parameters common to both SSFP cine protocols were: slice thickness = 8mm, slice gap = 2mm, FOV = 340×287mm^2 and GRAPPA rate 2 was used. The short TR protocol was used first. Following standard shimming, frequency scout was performed to determine the optimal synthesizer frequency for the high resolution protocol. After that, cines for the left ventricle were acquired using the standard protocol. Frequency scout was repeated when banding artifacts appeared in the myocardium. LV myocardial mass, end-diastolic volume (EDV), end-systole volume (ESV) and ejection fraction (EF) were analyzed using QMass MR (Medis, Netherland) with papillary muscles included in the left ventricle. 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.

Results The acquisition time of one slice was about 6 and 9 heart beats for the protocols with short and standard TR respectively. Banding artifact was common in cine images obtained with the standard TR protocol, while images from the protocol using short TR scan were impervious to the artifact (Fig. 1). LV function parameters measured from the two protocols were comparable and correlated well with each other, although statistically significant difference presented for myocardium mass (Fig. 2 and Table 1).

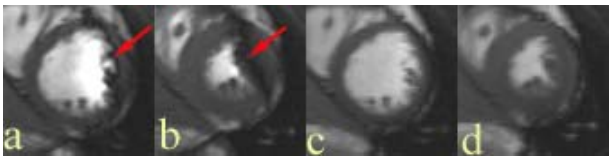

Fig 1 Typical ED (a, c) and ES (b, d) images from standard TR (a, b) and short TR (c, d) SSFP protocols.

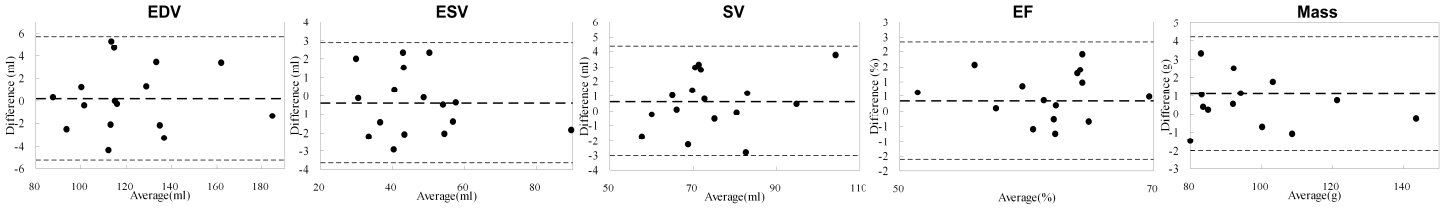

Fig 2 Bland-Altman plots of paired measurements of LV function. Dot lines represent mean value and 95% limits of agreement.

Discussion and conclusion

Supposed T1/T2 of myocardium at 3T to be 1100/80 ms, the allowed range of difference off-resonance frequency would be increased by 76.4 Hz when TR is reduced from 3.4ms to 2.7ms, demonstrating that the SSFP cine protocol using a shorter TR is more robust to field inhomogeneity at 3T. In addition, the shorter TR cine protocol increases patient throughput by eliminating the need for extra scans and shortens image acquisition time through reduced patient breath-hold time. Despite the slightly reduced spatial resolution, the short TR cines gave LV function measurements comparable to the standard protocol in both volunteer and patient studies. When there is a clinical need for higher spatial resolution (e.g., non-compaction cardiomyopathy), phase resolution may be increased to facilitate the visualization of myocardial structural details. Although the scan time would increase slightly in this case, the protocol's robustness to the banding artifact is still preserved because of the shorter TR used. In summary, the compromise of spatial resolution has little influence on LV function assessment in this study, and the proposed approach is a robust, fast and accurate way for SSFP cine, which will greatly benefit the adoption of 3T for CMR.

Table 1 LV function measurement.

	Standard TR	Short TR	*p*-value	*r*
EDV (ml)	121.6±24.1	121.8±24.2	0.77	0.99
ESV (ml)	47.2±14.2	46.8±13.8	0.36	0.99
SV (ml)	74.3±11.5	75.0±12.1	0.22	0.99
EF (%)	61.7±4.3	62.1±4.1	0.19	0.97
Mass (g)	92.6±18.9	93.7±18.2	0.02	1.00

References [1] Oshinski JN et al., JCMR 12:55, 2010; [2] Lee H et al., MRM 63(6), 2010.

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