Validation of Myocardial Motion Parameter Extraction from Cine Cardiac MR Against Tissue Doppler Echocardiography

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Introduction

The assessment of mitral annular tissue velocity plays an essential role in the evaluation of diastolic dysfunction. In echocardiography, there is a growing interest in the diagnostic and prognostic implications of measuring the velocity of myocardial tissue using Tissue Doppler Imaging (TDI) which derives values for peak velocities during systole (s'), early diastolic relaxation (e') and during atrial contraction (a'). We have previously shown that mitral annular velocities can be derived from standard four-chamber cine SSFP images by automatically detecting and tracking the mitral valve insertion points [1]. However, this method has not been validated against Tissue Doppler echocardiography, the standard clinical method for evaluating diastolic function. The objective of this study was to assess the accuracy of early and late diastolic (e' and a') mitral annular velocities derived from high temporal resolution SSFP cine by correlating with tissue Doppler echocardiography.

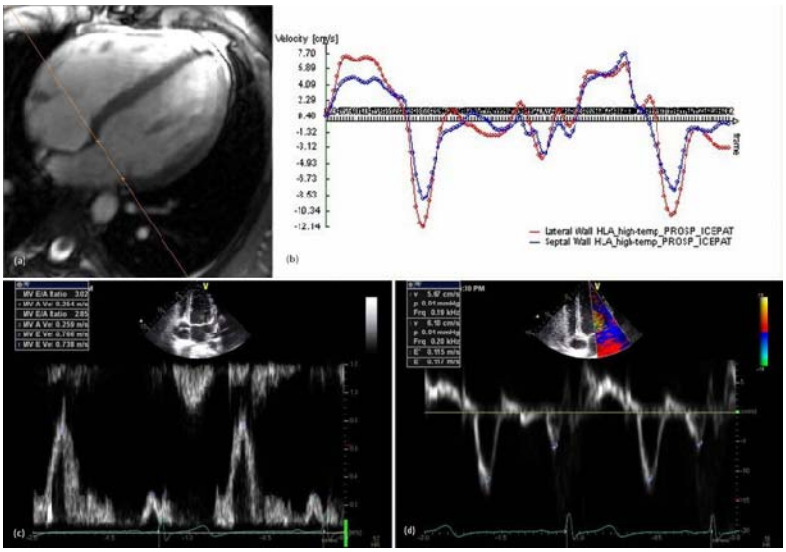

Figure 1. Mitral valve annulus velocity tracking in prospectively triggered MR (a), (b), mitral inflow velocity (c), and tissue velocities (d) from Doppler echocardiography. Mean lateral e' velocities are 11.6 cm/s (echo) and 11.9 cm/s (CMR), and mean lat a'.

Methods

The automated mechanism of tracking mitral valve insertion points on cine MR images (Fig. 1.(a)) throughout the cardiac cycle were already available as components of a commercial implementation of a completely automated ventricular function tool. (In-line VF, Siemens Healthcare) [2, 3]. The automatically generated velocities for each temporal frame in the cine sequence were plotted against time and the e' and a' value were identified as peak velocity at the time of early relaxation and atrial contraction for the lateral and medial mitral valve insertion point. Fig. 1(a) shows the detection of the mitral valve insertion points at the medial and lateral annulus, and Fig. 1(b) depicts the velocity/time curve as a result of the tracking for medial (blue) and lateral (red). The automated landmark tracking method was available as an offline-tool such that manual corrections could be performed if needed. Manual corrections were applied in the majority of the prospectively triggered data sets where more than one cardiac cycle was covered.

A cohort of 14 healthy volunteers (8 males, mean age 25.4 ± 6.2 yrs) gave informed consent to undergo CMR and echocardiography exams on the same day. Retrospectively and prospectively gated cine SSFP images in the four-chamber view were acquired during breath-hold on a 3T system (Siemens, Tim Trio). Rate 3 acceleration was used to achieve the following parameters: 17 ms true temporal resolution, 2.0 x 2.6mm x 8mm voxel size, 12-heartbeat duration. Mitral inflow peak velocity (E) was measured using retro-gated segmented PC: TR/TE = 4.5/1.9ms, 10mm slice, 100 x 192 matrix, TSENSE rate=3, VENC=150cm/s, true temporal resolution 36ms. Trans-thoracic tissue Doppler echocardiography was used to measure medial and lateral mitral annular tissue velocities and pulsed wave Doppler to measure inflow velocity for 3 consecutive heart beats and averaged. All acquisitions were made on a GE system using a 4Mhz 2-D probe and by placing a 5-mm sample volume at the tips of the mitral valve leaflets to obtain the mitral valve inflow. The temporal resolution was maximized with the setting to acquire at >70Hz (<14ms).

Results

There was substantial agreement between echo and CMR mean e' and a' velocities and E/e' ratios (Table 1) for medial and lateral annulus positions. The concordance correlation analysis of combined lateral and medial wall measurements revealed moderate concordance between echo and prospectively triggered (0.51) and retro-gated (0.53) e' as well as between echo and prospectively triggered (0.37) E/e'. Furthermore, the mean values for mitral inflow peak velocity (E) agree well between echo (67.2±13.0) and MRI (70.9±12.6). Although concordance in a' velocities was poor, the utility of this parameter in clinical practice is not clear.

	Medial		Lateral			Echocardiography					
	e'	a'	e'	a'	E/e'	Concordance			Two-tailed paired T-Test		
Acquisition Technique	Mean ± Std	Mean ± Std	Mean ± Std	Mean ± Std	Mean ± Std	e'	a'	E/e'	e'	a'	E/e'
Retrospect. CMR	11.07 ± 3.38	3.25 ± 1.11	15.34 ± 3.90	4.56 ± 1.55	5.63 ± 1.42	0.53	-0.04	0.37	0.388	<0.01	<0.01
Prospective CMR	10.32 ± 3.49	3.68 ± 1.34	15.08 ± 3.30	4.69 ± 1.26	5.87 ± 1.76	0.51	0.02	0.37	0.081	<0.01	<0.01
Echocardiography	11.88 ± 2.58	6.36 ± 1.27	15.56 ± 3.05	6.39 ± 1.54	5.02 ± 1.16	n/a	n/a	n/a	n/a	n/a	n/a

. Table 1. Mean e', a', E/e' velocities measured at medial and lateral myocardium wall from 14 healthy volunteers, as well as concordance correlation and the two-tailed paired T-Test results.

Conclusion:

Despite the two inherently different methods of measuring myocardial motion, there was moderate concordance correlation between CMR and echo measurement of e' and E/e' ratios. Mitral annular velocity can be measured accurately and extracted in a semi-automated fashion from high temporal resolution cine MR acquired in a reasonable breath-hold time. This method combined with mitral inflow velocities offers the potential for CMR to provide important information regarding diastolic function and filling pressures. Note that semi-automatic extraction of myocardial motion parameters is a current limitation as the algorithm is optimized for only 1 cardiac cycle. The derivation of strain information in a similar fashion from cine cardiac MR and the correlation against echo will be part of our future work.

References

[1] Weale, Guetter, et al., *JCMR* 2011; [2] Lu, Georgescu, et al., *MICCAI*, 2010; [3] C. Guetter, C. Chefd'Hotel,et al., *ISBI*,2011