Load-Independent Cardiac Function: Breath-hold Cine Imaging at 200 Hz.

H. V. Dinh[1,2], J. Child[3], E. Chan[4], V. Deshpande[5], J. P. Finn[2]

[1]Medcine/Cardiology, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [2]Radiology/Cardiovascular Imaging, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [3]Medicine/Cardiology, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [4]Medicine, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [5]UCLA Medical Center, Los Angeles, CA, United States

Background: Standard parameters of myocardial function, such as ejection fraction and cardiac index, are subject to the effects of preload and afterload (1). The isovolumic phases, which are theoretically load-independent, may be more representative of true myocardial performance (2). However, these phases are short-lived, lasting about 50-70 ± 20 ms, and are not amenable to assessment by conventional MR sampling frame rates of 40-50 frames/second (3). For these purposes, sampling rates on the order of 200 Hz are required, as in tissue Doppler imaging (4). **Purpose:** To implement a breath-hold cine technique with a sampling rate sufficient to image the load-independent contraction and relaxation phases of the heart (LIC and LIR, respectively). **Materials and Methods:** Seven consecutive subjects including five healthy volunteers (4 females, 1 male, average age 32) and two male patients with New York Heart Association class III-IV heart failure (1 nonischemic dilated and 1 valvular cardiomyopathy), were scanned using a high temporal resolution TRUFISP cine (5) sequence (TR/TE 5.1/1.1ms; FA 58°; FOV 236*360 mm; matrix 92*192; slice thickness 7mm; bandwidth 965 Hz/pixel) on a 1.5T MR system (Siemens Avanto) in the three orthogonal planes of the heart with the short axis slices (averaging 8-12 slices) covering the length of the ventricles. Parallel acquisition was used with an acceleration factor of two (6). LIC phase was defined as the total time (in msec) from QRS trigger to the image prior to the cephalad movement of the aortic valve leaflets as determined on the left ventricular outflow tract slice. LIR phase included time from the initial closure of the aortic valve to the apical movement of the mitral valve leaflets from its closed position. From these data, LIC and LIR times, volumetric changes and posterior mitral annular displacement and velocity as determined by the vertical long axis cine were obtained. Standard left ventricular global indices to include enddiastolic and endsystolic phases were also performed for comparison. Volumetric and mitral valve annular (MVA) changes were calculated with standard workstation postprocessing software (Leonardo Argus and Viewer, Siemen's Medical Solutions). SAS version 8.2 was used to generate Student's T-test for comparing differences in means between volunteers and patients and Pearson's test for assessing significance of univariate correlations between load independent and standard parameters. **Results:** All seven studies were technically successful with adequate spatial resolution to visualize endocardial and epicardial borders. A temporal resolution of 5.2 msec was achieved with up to 176 phases within the cardiac cycle. Healthy volunteers and patients differed significantly in their baseline standard LV global function (LV EF 68.1% versus 21.3%, $p<0.001$) and maximal posterior mitral valve annular displacement (17.2 mm versus 2.4 mm, $p=0.006$) as expected (Table 1). There were no difference in LIC and LIR times between the two groups (data not shown), but the study was not powered to detect this difference. CHF patients had a higher LIC average ejection rate and LIR peak filling rate than normals ($p=0.01$ and $p=0.038$, respectively). Patients also had a trend toward a lower LIC MVA displacement velocity ($p=0.06$). Load independent contraction and relaxation parameters show strong correlations with standard global LV functional indices (Table 2). The highest three correlations were LIC peak ejection rate with LV mass index ($R^2=0.9676$, $p<0.01$), LIC MVA displacement with EDVI ($R^2=0.8603$, $p=0.07$), and LIR peak fill rate with EDVI ($R^2=0.8069$, $p=0.03$). Representative LIC and LIR volume curves for a normal and patient subjects as well as high temporal resolution TRUFISP images for a patient is shown (Figure). **Conclusions:** Breath-hold cine was implemented with temporal sampling rates comparable to tissue Doppler. Up to 15 frames were sampled during the isovolumic phase of cardiac contraction, compared to 2 frames with standard cine. It is now possible to study morphologic changes in the LIC and LIR phases that may yield important insights on cardiac physiology. The load-independent parameters show strong correlation with standard LV global functional indices and may potentially be used as new markers distinguishing normal from abnormal systolic and diastolic function. Larger studies are required to validate this hypothesis. **References:** (1)MA Quinones, et al. *Circulation*, Vol 53, 293-302, 1976. (2) MR Starling, et al. *Circulation*, Vol 76, 1274-1281, 1987. (3) B. Lind, et al. *Eur J Echocardiography*, Vol 5, 284-293, 2004. (4) L. Brodin. *Clin Physiol Funct Imaging*, Vol 24, 147-155, 2004. (5) J. Carr, et al. *Radiology*, Vol 219, 828-834. (6) M. Griswold, et al. Magnetic Resonance in Medicine, 47:1202-1210, 2002.

Table 1. Standard and Load Independent Global Left Ventricular Functional Indices.

Parameters	Volunteer (N=5)	Patient (N=2)	P
LVEF (%)	68.1	21.3	<0.001
Stroke Volume Index (SVI) (ml/m^2)	48.8	26.9	0.034
Mitral Valve Annulus (MVA) Displacement (mm)	17.2	2.4	0.006
LIC Ave Ejection Rate (ml/sec)	0.055	0.242	0.01
LIC Peak Ejection Time (msec)	13.39	44.99	0.21
LIC MVA Displacement Velocity (mm/msec)	0.0711	0.0225	0.06
LIR Peak Filling Rate (ml/sec)	290.93	768.86	0.038
LIR Peak Filling Time (msec)	111.62	25	0.45

Table 2. Pearson Correlation Between Load Independent and Standard Global LV Functional Indices.

Dependent Variable	Independent Variable	R^2	P
LIC Peak Ejection Rate	Mass Index	0.9676	0.0025
LIC MVA Displacement	End Diastolic Volume Index (EDVI)	0.8603	0.0725
LIR Peak Fill Rate	End Diastolic Volume Index (EDVI)	0.8069	0.0384
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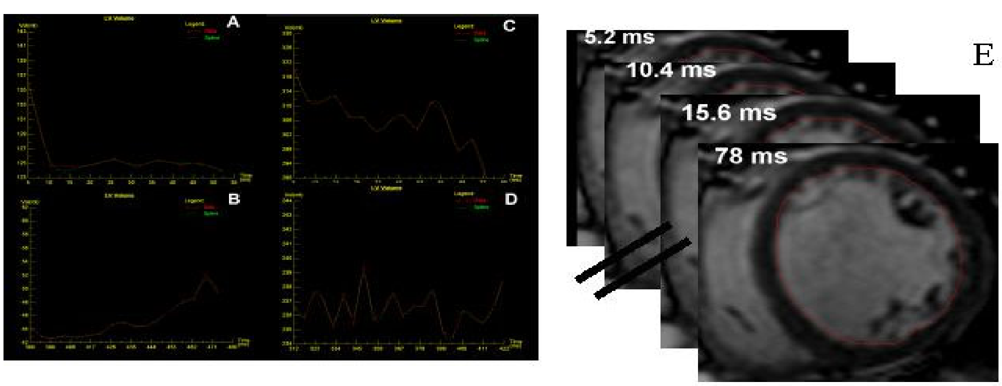

Figure. Load-independent contraction and relaxation volume curves for normal (A, B) and patient (C, D). TRUFISP high temporal resolution images with endocardial contouring from a patient (E).