Left Ventricular (LV) volume based indices for the evaluation of diastolic function using high frame rate cine SSFP imaging: Direct comparison with Doppler Echocardiography

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Introduction: Fifty percent of the heart failure patients have diastolic dysfunction with preserved ejection fraction (HFpEF) [1]. While cine cardiac MR (CMR) is routinely used to assess systolic function, assessment of diastolic function has remained in the domain of echocardiography because of its ability to measure blood flow velocities across the mitral valve, and the mitral annular velocities at very high temporal resolution. Matching the temporal resolution of echo with MR would prolong the breathhold time beyond the capacity of most HF patients. The purpose of this pilot study is three fold: (a) free breathing SSFP sequence that can obtain high (~ 10-14 ms/phase) cine imaging; (b) a volumetric analysis method to extract diastolic functional indices from the segmented time-volume curves, and (c) to compare the MR based diastolic functional indices against traditional echo-based diastolic function metrics such as early peak velocity (E) to peak velocity during atrial contraction (A) measured at the tip of the mitral leaflets.

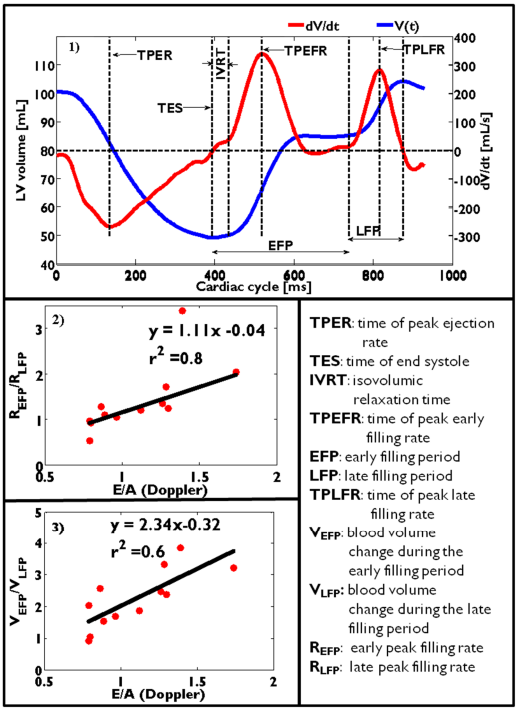
Materials and Methods: 11 subjects (11 M, age: 50 ± 12 yrs) provided written informed consent to participate in this IRB approved study, and underwent MRI and echocardiographic imaging as a part of a single imaging session, without getting off of the scanner table.

MRI: All subjects were imaged at 1.5 T (Philips, Achieva) with VCG gating using a 32 channel cardiac coil for signal reception. A custom respiratory-triggered, free breathing SSFP cine imaging sequence with the following acquisition parameters was used to obtain a stack of contiguous LV short axis cine SSFP images: TR/TE/flip: 3.2 ms/1.5 ms/55˚; acquired temporal resolution: 10-15 ms/phase; acquired spatial resolution: 2.25 x 2.25 x 8 mm; parallel imaging factor: 2; acquisition duration : 18 hb/slice. Details of the pulse sequence have been described by Pednekar et al. [2].

Echocardiography: Subjects were transported to ultrasound (Philips Healthcare, IE 33) on the same scanner bed to minimize physiologic variation and diastolic functional indices such as E/A ratio were obtained.

Data Analysis: SSFP cine MR data was transferred to a post-processing workstation (View Forum, Philips Healthcare) for further analysis. Endocardial contour was drawn at end-diastole by an expert observer, and this contour was propagated across the cardiac phases by an semi-automated algorithm. LV contours, thus drawn, were reviewed by an experienced observer and were manually adjusted if needed. From these contours, LV volume was determined for each cardiac phase. This time-LV volume curve was further analyzed using custom-written software in MATLAB™. The raw LV volume curve was up-sampled by a factor of 4, and the derivative of the time-volume curve was estimated using the method described by Ramkumar et al. [3] (Figure 1), to identify various events during the cardiac cycle.

We defined the following MR based diastolic functional indices: (a) ratio of the blood volume change during the early filling period (EFP) (defined as the duration between time to end systole (TES) to time to onset of atrial contraction) to the blood volume change during the late filling period (LFP, atrial contraction) – V_{EFP}/V_{LFP}, and (b) ratio of early peak filling rate to the late peak filling rate - R_{EFP}/R_{LFP}. These metrics are the MR equivalent surrogates of velocity based echo index of E/A ratio.



Results: High frame rate cine SSFP sequence during free breathing provides cine MR images with adequate temporal resolution to estimate MR based indices of diastolic function. Doppler based E/A ratios were in good agreement with MR based indices such as V_{EFP}/V_{LFP}, and R_{EFP}/R_{LFP} (Figures 2,3).

Discussion: For heart failure patients, the ability to obtain high temporal resolution cine imaging under free breathing conditions is an attractive alternative to repeated breathholding. Furthermore, such high temporal resolution cine images will make it possible to evaluate both systolic and diastolic function – a necessary evaluation to assess heart failure patients with preserved ejection fraction (HFpEF). It is important to note that the diastolic functional indices described here for MR are fundamentally different (volume based for MR, versus velocity based for echo) from traditional echo-based indices that rely on the measurement of instantaneous velocities.

Conclusions: The results from this pilot study suggest that it is feasible to evaluate both systolic and diastolic function with a single set of high-temporal resolution cine SSFP images acquired during free breathing. The potential utility of this method has to be tested in a cohort of heart failure patients.

References: 1. CW Yancy et al. Circ, 2013; 128:e240-327. 2. Pednekar et al. ISMRM 2012, 3938. 3. Ramkumar et al. *JMRI*, 31(4), 872-880