2D Cardiac Function during Free-breathing with Navigators

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Introduction: Free-breathing (FB) cardiac MR (CMR) imaging of myocardial function would be a useful alternative to eliminate repeated breath-holding, e.g. during a stress study. Imaging with multiple breath-holds (BH) commonly leads to slice misregistration, due to breath-hold variability, resulting in unevaluated segments of the myocardium. Free-breathing cardiac function has been investigated previously using real-time methods, respiratory bellows [1], and self-gating with radial interleaves [2]. Here are presented the results of a navigator-gated (NAV) 2D SSFP cardiac function acquisition, based on recent work using NAVs [3-5] for phase-contrast.

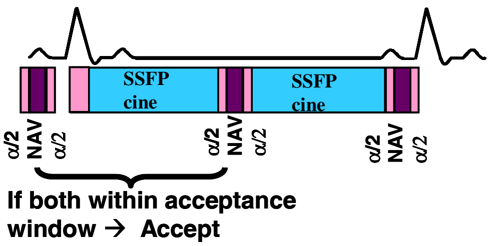

Figure 1: 2 NAVs are used as acceptance criteria for 2D FB cine.

Methods: 5 healthy subjects were studied (4 F, average age 22) on a 1.5 T Philips Intera Achieva (Best, NL). Free-breathing cardiac function data were acquired with a 2D SSFP undersampled radial acquisition. Navigators (25 ms in duration each) placed just prior to the QRS, and ~500 ms after the QRS were used (Fig. 1). Data collected during a heart beat were accepted if these two NAVs were both within the 5 mm acceptance window, providing less motion compensation for the latter half of the cardiac cycle. The NAVs were surrounded by α/2-TR/2

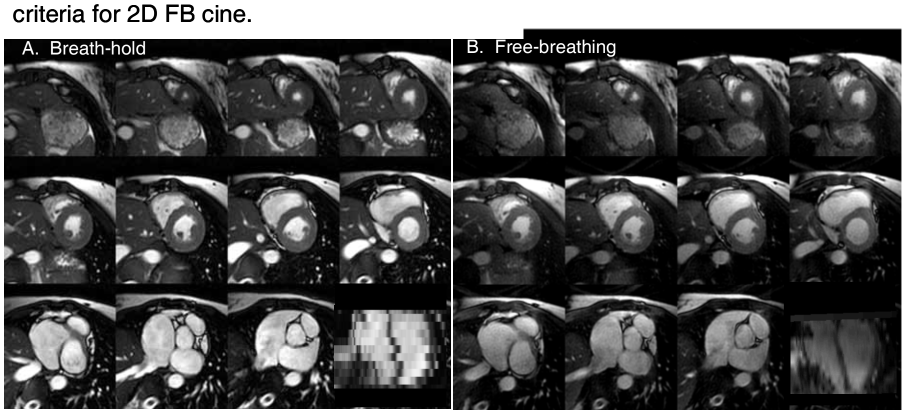

Figure 2: A) 2D breath-held cine obtained during 12 BHs, and B) 2D free-breathing radial cine. All 12 slices are shown at end-systole. The long-axis reformats compare slice registration for the 2D BH and FB techniques in the same volunteer.

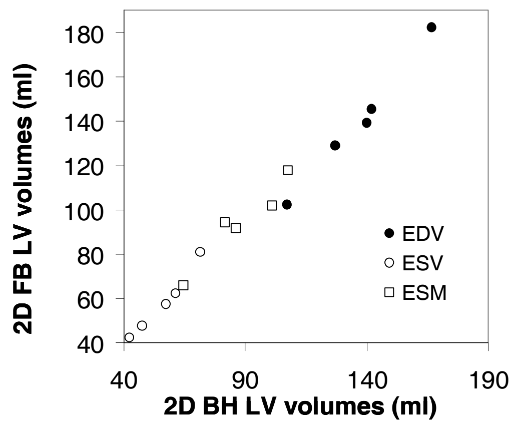

Figure 3: LV volumes (end-systolic and end-diastolic and mass (ESM) measured by 2D FB vs. 2D BH.

store/restore sequences. The parameters were: TR/TE/θ= 3.1ms/1.5ms/40º (flip chosen to reduce SAR during the ~4 minute scan), 16 cardiac phases acquired with prospective ecg-gating, with ~*20* views per segment acquired, 60 heart-beat scan time, 2 x 2 x 8 mm spatial resolution, 160 x 80 Np, acquired with interleaving which alternated with each cardiac phase, 320 cm FOV, 12 slices, 2mm skip. Images were reconstructed offline, using regridding, FFT and UNFOLD processing (6). For comparison, conventional 2D breath-hold cine imaging was performed using the following sequence: TR/TE/θ= 3.1ms/1.5ms/60º, 30 cardiac phases reconstructed using retrospectively ecg-gating, with ~*12* views per segment acquired, 12 heart-beats per slice, 2 x 2 x 8 mm spatial resolution, 160 x 160 Ny , 320 cm FOV, 12 slices in 12 breath-holds, 2mm gaps. SNR was measured in a single basal end-systolic slice. Noise was estimated as the standard deviation in the myocardial ROI. The left ventricular volumes and mass were measured from the short-axis data, using ROIs and computer aided planimetry.

Results: Figure 2 compares a 2D stack of short-axis slices with breath-holds (A) and with free-breathing (B). Some slice misregistration was visible in the long-axis reformats of all 2D BH scans (Fig. 2), and none in the 2D FB scans. For the FB scans, the quality of the initial cardiac phase is reduced by an imperfect transition to steady state. Average scan time with the BH method, including resting periods, was 10 minutes and for FB method 3.7 minutes with an average NAV efficiency of 27 %. The average myocardial and blood SNR were measured to be 16 and 52 for 2D BH, and 13, 23 for 2D FB respectively. The low flip angle used for FB method (40º vs. 60º for BH) is expected to result in a higher myocardial to blood signal ratio, as observed. Figure 3 plots LV volumes (end-diastolic and end-systolic and mass in grams) of 2D FB vs. 2D BH, with the correlation coefficient of R=0.99.

Discussion and Conclusions: 2D free breathing cardiac function imaging is possible using NAVs for respiratory-compensation. The two NAVs provide efficient respiratory motion compensation for complete assesment of the first half of the cardiac cycle, i.e.systolic function. Quantitative comparisons of LV volumes with the 2D gold-standard show good correlation. The advantages of registered slices, free-breathing acquisition and high NAV efficiency are important factors for improving assesment of function during stress.

References: 1) Alley MT et al., JMRI, 1999 9; 751. 2) Leung A, Thompson RB, ISMRM 2006 144. 3) Stehning C et al. ISMRM 2005, 1616. 4) Nezafat R et al. SCMR 2005, 424. 5) Jung BA et al. JMRI 2006 24:1033. 6) Madore B et al. MRM. 1999;42:813-28.