Whole Heart Cine MRI Using Real-Time Respiratory Self-Gating

S. Uribe[1], V. Muthurangu[2], R. Boubertakh[1,3], T. Schaeffter[1], R. Razavi[1], D. L. G. Hill[3], and M. S. Hansen[2]

[1]Interdisciplinary Medical Imaging Group, Division of Imaging Sciences, King's College London, London, United Kingdom, [2]Cardiothoracic Unit, Institute of Child Health, University College London, London, United Kingdom, [3]Center for Medical Image Computing, University College London, London, United Kingdom

Introduction: Isotropic non-angulated 3D cardiac MR has previously been investigated as a way of simplifying cardiac MRI [1]. A fundamental problem with 3D cine techniques is the attendant difficulties with respiratory compensation. Undersampling techniques have been used to acquire 3D cine data sets in a single breath-hold, however the spatio-temporal resolution available in a clinically feasible breath-hold is inadequate. A static 3D whole heart dataset can be acquired in a free-breathing scan by using navigator beams, however they disturb the steady state signal in SSFP cine sequences and are time consuming. Here, we present a general approach for 3D cine whole heart imaging using real-time respiratory self-gating from *k*-space center profiles, which has been implemented on a clinical scanner. The results of this respiratory gating approach are compared with non-gated free-breathing scans. A preliminary comparison of volume measurements from the new 3D cine and the standard 2D protocol has been done.

Method: A segmented balanced SSFP cine sequence was modified by adding a center profile ($k_y = k_z = 0$) at the beginning of each *k*-space segment. The breathing motion was derived by using this *k*-space center profile and the acquisition scheme was adjusted in real-time to re-acquire motion corrupted data. The respiratory phase was detected by calculating the correlation coefficient between a 1D Fourier Transform of each profile with a reference projection (determined in an initial 4 seconds breath-hold stage). The data were accepted if the correlation coefficient was within a certain acceptance window, defined as a percentage of the range of the correlation coefficient (calculated in a previous learning stage immediately after the breath-hold stage). In order to avoid a long scan due to changes in the breathing pattern, a drift correction was achieved by re-initialization of the reference projection.
Non-angulated isotropic 3D data with and without respiratory gating was acquired in a 1.5T Achieva scanner (Philips Medical system, Best, The Netherlands) and then reformatted into 2D clinical views in five healthy volunteers. The acquired spatial resolution was 2.5 mm^3 with 15 cardiac phases. The flip angle was 60° and TR/TE = 3.1/1.6 ms. A short-axis 2D acquisition with spatial resolution of 2.2x2.2x10 mm^3 (10 slices) and 30 cardiac phases was acquired for volume comparison.

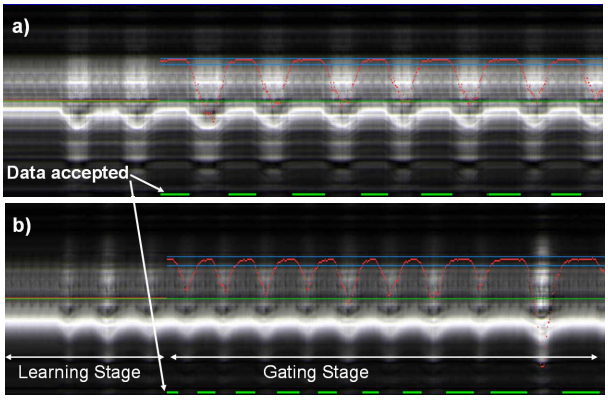

Figure 1. The projections, gating signal (in red) and windows of acceptance (blue lines) of a) one male and b) one female volunteer during the first 50 seconds of the scan. These pictures were obtained during the scan in the NAV display.

Results: A respiratory gating signal (Fig 1) was obtained in all volunteers. Using an acceptance window of 15%, the time required for the gated scans was twice as long as the non-gated scans (150 sec). Figure 2 shows a comparison of 3D reformatted data with and without this respiratory gating approach. Notice the reduced blurring and the improved delineation of the myocardial border in the gated exams. However, a reduction of image contrast was noticed in 3D cine techniques in comparison to the 2D acquisition [2]. A quantitative analysis between breath-hold multi-slice and 3D reformatted data shows a good agreement for all of the functional parameters using both techniques. (e.g the median and range values for the stroke volume in the left ventricle were 83.0 (74.4 - 123.8) [ml] and 83.3 (74.2 - 115.3) [ml] using the 2D and the 3D technique respectively)

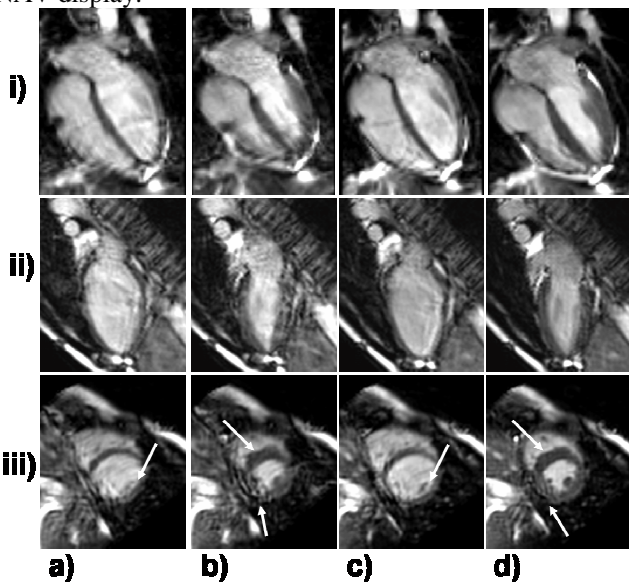

Figure 2. Representative end-diastolic (a,c) and end-systolic (b,d) frame of 3D reformatted data in i) four chamber, ii) two chamber, and iii) short axis views for one volunteer without (a,b) and with respiratory gating (c,d)

Discussion and Conclusion: The feasibility of real-time respiratory self-navigation for whole heart 3D cine imaging in a clinically reasonable time has been demonstrated in healthy volunteers. Motion artifacts are reduced in free-breathing images by forcing re-acquisition of motion corrupted data. This new technique represents a practical advance for an easier cardiac MR examination, since it reduces time for scan planning and provides patient-friendly free-breathing examination. For more detail see reference 3.

References: [1] Sorensen et al. Circulation 2004. [2] Nehrke et al. ISMRM 2006. [3] Uribe et al, *In Press* MRM 2006.