Respiratory Self-gated 4D Coronary MRA

P. Lai[1], A. C. Larson[1], J. Park[2], J. C. Carr[1], D. Li[1]

[1]Departments of Biomedical Engineering and Radiology, Northwestern University, Chicago, IL, United States, [2]Siemens Medical Solutions, Erlangen, Germany

Introduction:

Cardiac and respiratory motion artifacts have been the major problems that limit the clinical value of coronary MRA. Traditional ECG triggering is intended to suppress cardiac motion by synchronizing data acquisition with mid-diastole of a cardiac cycle. However, it is tedious to properly set trigger-delay times and acquisition window durations, which are both subject-dependent and coronary-dependent [1]. Breath-holding freezes respiratory motion of the heart during a scan, but restricts the achievable slice coverage and spatial resolution. Although diaphragmatic navigator (NAV) enables free-breathing high-resolution coronary MRA, it is incompatible with time-resolved imaging and suffers from hysteretic problems due to indirect measurement of heart position. Here, we present a new respiratory self-gating (RSG) technique for 3D cine (4D) coronary MRA which derives real-time RSG signal directly from the heart motion and is capable of achieving continuous phase images depicting cardiac motion of the coronary arteries over the entire cardiac cycle.

Materials and Methods:

A new sequence was implemented based on a SSFP cine sequence with retrospective ECG gating and Cartesian k-space sampling. As shown in Figure 1, an additional k-space center line for RSG [2] was acquired before each segmented data acquisition. Acquisition of each segment of k-space lines was repeated for 4~5 seconds to cover a complete respiratory cycle. The readout direction was along the maximal in-plane respiratory motion of the heart. Data were continuously acquired throughout the scan and retrospectively remapped into the nearest cardiac phase of 15 evenly spaced cardiac phases based on the ECG time stamp simultaneously recorded. By analyzing 1D projections reconstructed from the RSG k-space lines, cardiac phase-dependent profile templates were generated. Breathing-induced heart displacement during acquisition of each RSG line was derived by phase-dependent template matching and used for respiratory gating and motion compensation. Adaptive averaging of sufficiently correlated k-space lines was implemented to increase SNR. A phase-sensitive method was applied for fat saturation [3].

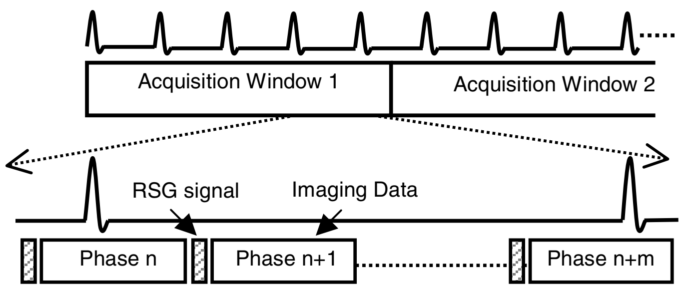

Figure 1. Diagram of the 4D RSG sequence

Coronary arteries of 8 healthy volunteers were scanned using a 1.5T Siemens Sonata system during free breathing. Sequence parameters included: 350×250 mm^2 FOV, 8 partitions interpolated from 4, 1.75 mm slice thickness, 256×154 acquisition matrix, 1.4×1.6 mm^2 in-plane resolution, 60º flip angle, TR/TE=4.30/2.15 ms, 11 lines/segment. Image quality and coronary artery delineation was graded by two blinded reviewers (1: worst; 4: best) and comparison was made between self-gated images and images reconstructed using signal averaging from the same data measured to assess the effectiveness of RSG.

Results:

Figure 2.a shows a segment of the original position shift signal derived using template matching. After low-pass filtering (LPF, cut-off frequency≈0.6 Hz), smooth RSG signal representing breathing-induced heart displacement was obtained (Figure 2.b).

Figure 3 shows the maximum intensity projection (MIP) images of RCA reconstructed using RSG at 3 different diastolic cardiac phases. Obviously, the coronary artery is best visualized in the mid-diastole image. In comparison, the coronary artery is blurred by severe motion artifacts in the corresponding mid-diastole image reconstructed using simple signal averaging. Paired t-test revealed significant improvement ($P<0.001$) in coronary artery delineation and overall image quality with self-gating as compared to simple signal averaging.

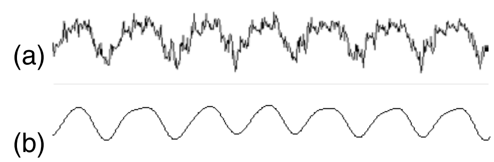

Figure 2. (a) position shift of the RSG projection derived using template matching and (b) the RSG signal after LPF

Conclusion:

The proposed 4D RSG technique is promising for free-breathing high-resolution 4D coronary MRA. With continuous data acquisition and retrospective ECG gating, steady state signal is better preserved and cardiac motion is also resolved. With this technique, no pre-determined trigger-delay time and acquisition window is needed and images with the best delineation of the coronary arteries can be selected retrospectively for diagnosis.

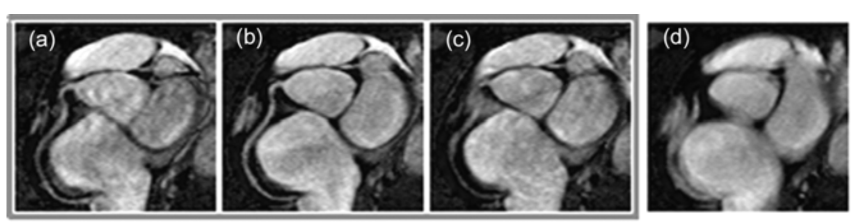

Figure 3. MIP images of self-gating at early-diastole (a), mid-diastole (b), late-diastole (c) and the MIP image of simple averaging at mid-diastole (d)

Reference:

[1] Bi X, et al. MRM, 2005, 54:470; [2] C. Stehning, et al. MRM, 2005, 54:376; [3] Park J, et al. MRM, 2005, 54:833