ECG-gated First-pass Contrast-enhanced Magnetic Resonance Angiography of the Thorax - Initial Experience in Healthy Volunteers and Patients

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Background: Prior implementations of cardiac-gated CEMRA have been limited by restricted anatomic coverage due to the acquisition of only a single 3D partition per heartbeat, effectively precluding high spatial resolution imaging of the entire thorax1. Objectives: To evaluate the feasibility of ECG-gated first-pass CEMRA of the entire thorax using a novel k-space segmentation scheme.

Methods: Eight volunteers and 20 consecutive patients underwent prospectively ECG-gated first-pass CEMRA at 1.5 Tesla (Magnetom Avanto; Siemens Healthcare, Germany) under an IRB approved protocol with the following acquisition parameters: coronal, breath-held, 3D spoiled gradient echo sequence; TR 2.7 msec; TE 0.9 msec; flip angle 25°; parallel imaging acceleration (GRAPPA) factor 3; matrix 288 x 512; in-plane resolution 1.3 x 1.0; slice resolution 1.88 mm, interpolated to 1.3 mm; 120 - 128 slices (IPR#573: Gated CEMRA, Siemens Healthcare, Germany). During each heartbeat, multiple in-plane (k_y) and thru-plane (k_z) phase encoding steps were acquired in a saw tooth-like pattern (acquisition window per heartbeat: 822 ± 143 ms; acquisition of all phase encoding steps from 3 – 5 phase-encoding loops (k_z)). The center of k-space in the thru-plane phase encoding direction (k_z=0) was acquired during diastole, while the center of k-space in the in-plane phase encoding direction (k_y=0) was further synchronized with the contrast bolus peak. ECG-gated CEMRA images were compared intra-individually (volunteers) and inter-individually (patients) to non-gated CEMRA with identical acquisition parameters. The sharpness of the aorta was quantitatively evaluated in healthy volunteers on source images by plotting the signal intensity (SI) profile across the vessel wall and measuring the distance D between 80% and 20% of maximal SI on both sides of the vessel wall (Figure 1). Sharpness = 1 / D. The presence of artifacts and the visualization of thoracic vasculature and cardiac chambers were subjectively evaluated in patients.

Results: ECG-gated CEMRA depicted the aortic root with greater sharpness than non-gated CEMRA (0.40 ± 0.11 vs. 0.21 ± 0.07, respectively; p = 0.01; Figure 1), while sharpness of the descending thoracic aorta was unchanged (0.42 ± 0.05 vs. 0.42 ± 0.05, respectively; p = 0.89). Subjective evaluation of motion artifacts showed that ECG-gating significantly reduced blurring on coronal and oblique source images (Figure 2A and 2B; p < 0.001). On axial reconstructed ECG-gated CEMRA images, however, edge ghosting artifacts of moderate intensity were present on 12 of 20 patients in the thru-plane phase encoding direction (Figure 2D). In one patient, these ghosting artifacts were severe. Definition of the ascending aorta (p = 0.037), the right atrium (p = 0.001), the right ventricle (p < 0.001), and the left ventricle (p < 0.001) was significantly better on ECG-gated CEMRA compared to non-gated CEMRA (Figure 2). ECG-gating also improved the image quality rating of the aortic root and the left atrium, but the difference was not statistically significant (aortic root: p = 0.088; left atrium: p = 0.065). Both non-gated and ECG-gated CEMRA depicted the aortic arch, the descending thoracic aorta, the pulmonary arteries, and the pulmonary veins with similar image quality. Mean breath-hold time of ECG-gated CEMRA was 30% longer than non-gated CEMRA (volunteers: 27.8 ± 2.3 sec vs. 20.9 ± 0.0 sec, p < 0.01; patients: 26.3 ± 3.9 sec vs. 18.9 ± 1.0 sec; p < 0.01).

Conclusion: ECG-gated first-pass CEMRA of the entire thorax is now feasible and the proposed pulse sequence overcomes the coverage limitations inherent in prior implementations of ECG-gated first-pass CEMRA.

Figure 1 Sharpness of the aortic root on non-gated (A) and ECG-gated CEMRA (C). Sharpness was determined on the SI profile across the vessel wall (B and D). Sharpness of the aortic root on non-gated and ECG-gated CEMRA was 0.19 and 0.54, respectively.

Non-gated CEMRA  ECG-gated CEMRA

Figure 2 Interindividual comparison of non-gated (A, C, E) and ECG-gated (B, D, F) CEMRA in two patients. Mild edge ghosting artifacts are indicated with arrow (D).