# Self-Gated Free Breathing 3D Coronary Cine Imaging With Enhanced Artery Contrast by Exploiting the Simultaneously obtained Water and Fat Visualization

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## INTRODUCTION

In this work, a respiratory and cardiac self-gated free-breathing 3D cine SSFP imaging technique is proposed utilizing multiple echo acquisitions to separate water and fat for optimal visualization of the coronary arteries. Multi-echo hybrid radial sampling has been shown to have a high data acquisition efficiency and a high robustness to motion. By frequently acquiring the k-space centers along the slice encoding direction, both respiratory and cardiac motions are derived without a scan time increase. In this study, 3D images from different echo times are reconstructed and processed to perform water-fat separation to visualize coronary arteries in a high-resolution free-breathing acquisition. Combination of the water and fat images further improves the coronary artery contrast.

## MATERIALS AND METHODS

We used a multi-echo sequence that has a radial acquisition in-plane and Cartesian encoding through-plane [1]. The data sets acquired at different echo times were used to separate water and fat signals [2]. Data were continuously acquired to avoid interrupting the SSFP steady state and to generate cardiac phase resolved images, eliminating the need for a patient specific trigger delay as in conventional ECG gated coronary MRA. The cardiac phase presenting the coronary arteries best could be selected retrospectively. No dedicated preparation pulses such as navigator, $T_2$-prep and fat-suppression pulses were used. A golden-ratio-based angle view order was applied to achieve flexible view sharing and high temporal resolution [3,4]. Respiratory and cardiac motion information was extracted from the image data itself [1] without the use of external respiratory or cardiac gating signals. Although the fat images are usually discarded, we propose a novel method for improving the contrast of coronary MRA by combining the water and fat images. The idea is to mask the water image with the complement of the fat image. The 3D cine coronary MRA parameters were: TR/TEs=5.0ms/0.3/1.6/2.9ms, FA/BW/FOV=40°/±125kHz/26cm, spatial resolution=1.0x1.0x3.0 mm, 14-16 slices, on a 1.5 T GE EXCITE 14M4 scanner. Temporal resolution was 70-80 ms and scan time was 5 min with 50% respiratory self-gating efficiency.

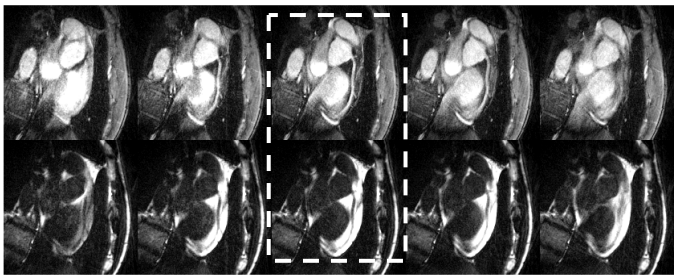
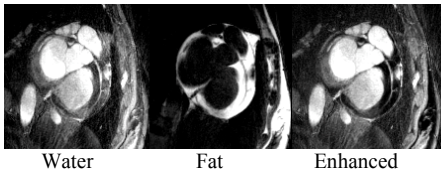


**Fig.1** Coronary water (top row) and fat (bottom row) cine images obtained from a healthy volunteer. Five representative cardiac phases at every other phase are shown. The best visualization of the coronary artery can be selected retrospectively (dashed white box).

Conventional breath-hold ECG triggered 3D Cartesian images were acquired for comparison. Imaging parameters were 200 ms data acquisition window, 24 heartbeats scan time, 1.0x1.6x3.0 $mm^3$ spatial resolution. Free-breathing diaphragm navigator (NAV) gated 3D Cartesian images [5] were also acquired with scanning parameters 128 ms acquisition window and 1.0x1.0x3.0$mm^3$ spatial resolution. Using PAWS, the respiratory gating window was set to 5 mm, and the scan time was 5.1±1.3 min with 43%±12% respiratory gating efficiency. Spectrally selective RF pulses were used for epicardial fat suppression for both breath-hold and free-breathing 3D Cartesian imaging techniques. 10 healthy volunteers were imaged. Both RCA and LAD were imaged in randomized order. An experienced radiologist scored vessel depiction using the following scale: 4-excellent, 3-good, 2-fair, 1-poor, 0-not seen.



Water Fat Enhanced

**Fig.2** Combining the water and fat images enhances the coronary artery contrast.

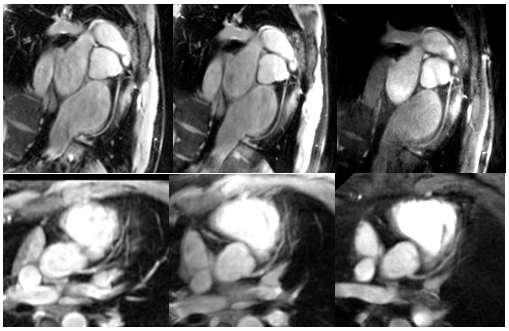


**Fig.3** RCA (top row) and LAD (bottom row) images acquired with breath-hold (left column), free-breathing NAV (middle column), and self-gated free-breathing techniques (right column).

## RESULTS AND DISCUSSION

Water and fat cine images of the coronary arteries are shown in Fig. 1. The dashed box indicates the cardiac phase retrospectively selected for its clearest depiction of the coronary artery. Fig. 2 demonstrates the improvement in coronary artery contrast by the combination of the water and fat images. Comparisons of breath-hold, free-breathing NAV and the proposed self-gated free-breathing techniques are demonstrated in Fig. 3. The mean scores of the vessel depiction over 10 subjects are shown in Fig. 4. There is no statistically significant difference for the vessel depiction scores among the three methods (p-value >0.05). In this study, water and fat separation worked well even without considering the local field inhomogeneities. Further improvement may be expected by including local inhomogeneities. Further investigations also include optimizing the combination of water and fat images for enhancing the coronary artery contrast.

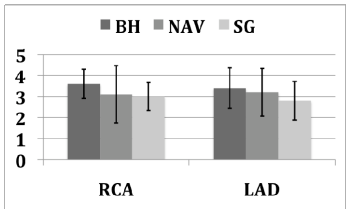



**Fig.4** Average scores of vessel depiction with breath-hold, free-breathing NAV, and self-gated free breathing techniques (10 volunteers).

## CONCLUSIONS

A new free-breathing 4D coronary MRA technique is proposed, which does not require external respiratory and cardiac gating, or dedicated preparation pulses, and generates cardiac water and fat cine images in reasonable scan time. Preliminary results demonstrate that this technique provides comparable vessel depiction to those of conventional breath-hold and free-breathing NAV imaging techniques.

**REFERENCES 1.** J Liu, et. al., MRM, 63, p194. **2.** GH Glover, et. al., MRM, 18, p371. **3.** S Winkelmann, et. al., IEEE-TMI, 26, p68. **4.** J Liu, et. al., IEEE-TMI, 25, p148. **5**. TD Nguyen, et. al., JMRI, 28, p509.