Contrast-Enhanced Whole-heart Coronary MRA with Self-Timing and Respiratory Self-Gating

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Introduction: Contrast-enhanced coronary MRA (CE-CMRA) was proven to provide high SNR and CNR for coronary artery delineation. Recently, whole-heart CE-CMRA was developed to further improve ease-of-use and vessel coverage [1]. However, the transit time from contrast injection to peak arterial enhancement varies largely among different subjects and injection schemes. Moreover, the whole-heart approach necessitates slow contrast-agent infusion and free-breathing. Therefore, optimal imaging timing is further complicated by simultaneous myocardium enhancement and variations in heart rates and breathing patterns. Also, accurate measurement of breathing-induced heart motion remains critical for high-quality CMRA. This study aimed to develop a new technique for whole-heart CE-CMRA with both self-timing of data acquisition and self-gating for resolving respiratory motion.

Methods: A new sequence was implemented for this study based on a navigator (NAV)-gated ECG-triggered segmented FLASH sequence. In each cardiac cycle, an additional RSG k-space line, a center k-space line of a whole-heart slice along the superior-inferior (SI) direction, was collected in-between NAV echo and imaging data. Regional saturation was performed prior to RSG data acquisition to suppress residual chest wall signals. Studies were conducted on health volunteers using a 3T Siemens Trio MR system with slow-infusion of Gd-BOPTA [1]. Each volunteer was scanned using conventional and new sequences in two separate studies. For the former, data acquisition started 30 sec after contrast administration using a linear partition-encoding scheme. For the latter, imaging was self-timed using center-out partition-encoding. Whole-heart CE-CMRA was performed using the following parameters: 320×250 FOV; 110mm slice thickness; 320×240 matrix; 64 partitions interpolated to 128; 45 lines/segment; TR/TE = 3.0/1.56ms; 20º flip angle; TI = 200ms. All imaging was gated using NAV (±3mm) and motion compensation was applied off-line using both NAV and RSG.

From each RSG k-space line, a RSG projection of the heart could be reconstructed and used for both self-timing and self-gating. **Self-timing**: The signal integration over the heart region of the projection is correlated with cardiac-blood enhancement. As depicted by the variation of the RSG projection signal (Fig.1), contrast kinetics exhibits a relatively rapid rising phase followed by a prolonged blood-enhancement period. For self-timing scans, imaging was started at the moment when the intensity increment percentage decreased to <10%. **Self-gating**: With high blood-background contrast in CE-CMRA, the heart shows a distinctive profile in the RSG projection. With slow contrast-agent infusion, cardiac-blood signal primarily undergoes overall enhancement and decay, such that the heart profile is relatively consistent during the scan (Fig.1). Correlation coefficient (CC) was used to derive the profile shift of each RSG projection from an end-expiration reference [2]. To adapt to slight contrast-induced profile deformation, the heart region of the RSG projection was segmented into 5 sub-regions. Profile matching was performed separately in each sub-region and the shift providing the maximum total CC value was regarded as the derived heart displacement.

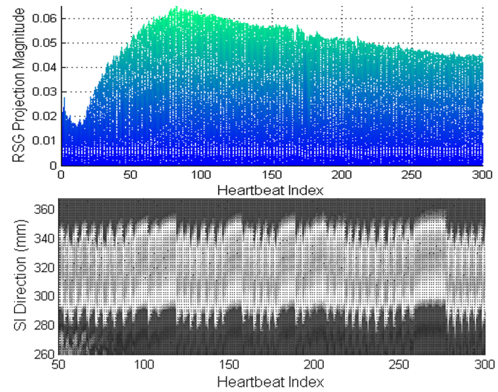

Fig.1. The magnitude change (upper) and the profile shift (lower) of the RSG projection during a scan.

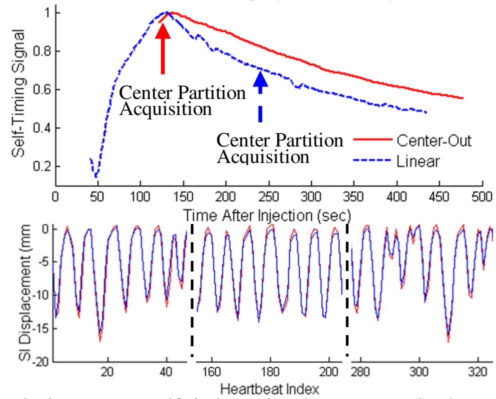

Fig.2. Upper: self-timing signals; Lower: SI heart motion detected by NAV (red) and RSG (blue).

Results: Fig.2 (upper) shows the self-timing signals from the two studies on a single subject. For the conventional approach, center partitions were acquired at a post-peak period with reduced blood signal and relatively high myocardium signal. In comparison, self-timing ensures center k-space acquisition at the peak arterial enhancement. As shown in the lower figure, the NAV and RSG motion signals are highly correlated throughout the scan. As shown in the reformatted images in Fig.3, self-timing clearly provides better image quality with higher SNR and CNR. Compared to the NAV image, the medial segment of RCA is better delineated in the RSG image. Overall, self-timing improved SNR and CNR by 35% (38.7±10.1 vs. 28.7±1.7) and 39% (26.5±5.1 vs. 19.0±0.9), respectively.

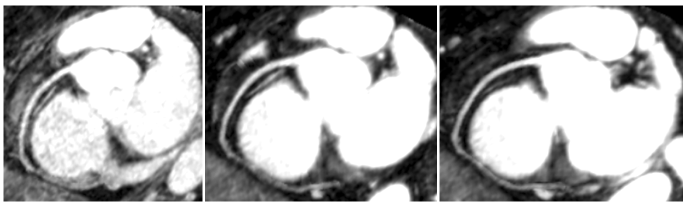

Fig.3. RCA images acquired with conventional timing (left) and self-timing (middle:NAV; right: RSG).

Discussion: The conventional approach for whole-heart CE-MRA suffers from reduced arterial blood signal and myocardium enhancement due to suboptimal timing of data acquisition, while the proposed self-timing approach can improve both SNR and CNR. The RSG method works reliably at the presence of contrast agent and can potentially better suppress respiratory motion with regard to NAV. Future work will involve additional volunteer studies and systematic comparisons.

References: [1] Bi X et al, MRM, 2007; [2] Lai P et al, ISMRM 2007, p21.