High Resolution True-FISP Coronary MRA with Self-Calibrating Partially Parallel Acquisition

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Introduction

Coronary magnetic resonance angiography (MRA) requires high spatial resolution and signal-to-noise ratio (SNR) for reliable visualization due to the small size of coronary arteries. Three-dimensional (3D) True-FISP (fast imaging with steady state precession) has made it possible to obtain adequate SNR in a single breath-hold (1). However, high-resolution breath-hold coronary MRA has not been amenable by the limited imaging time. Partially parallel acquisition (PPA) techniques have been recently introduced to reduce the imaging time. In this work, instead of releasing the constraint of the imaging time, a k-space based PPA technique, GRAPPA (GeneRalized Auto-calibrating PPA) (2), is used to increase the spatial resolution in a breath-hold coronary MRA under the same imaging time as conventional data acquisition. Images reconstructed with conventional sampling and with GRAPPA are compared qualitatively and quantitatively.

Methods

Seven healthy volunteers were studied on a 1.5T Siemens Sonata system. Coronary arteries were imaged using an ECG triggered, breath-hold, segmented 3D True-FISP sequence (1). Either LAD (left anterior descending) or RCA (right coronary artery) was imaged in each volunteer. Two images were generated for the same coronary artery: one with the root sum of squares reconstruction using the conventional sampling and the other with GRAPPA reconstruction (2) using variable-density accelerated sampling.

For the GRAPPA acquisition, each coil k-space was sampled by an acceleration factor of 2. Eight additional auto-calibration signal (ACS) lines in the central region of k-space were measured to calibrate coil weights. An eight-channel phased array coil (4 anterior and 4 posterior to the heart) was used. The imaging parameters were: TR/TE/flip angle = (3.4-3.7) ms/(1.3-1.5) ms/70^{o}, FOV = (200-225) $\times$ (340-380) mm^2, data acquisition matrix = 124 $\times$ 512, number of lines/heartbeat = 31, total imaging time = 18-20 sec, number of partitions = 6 (interpolated to 12), slice thickness = 3 mm (interpolated to 1.5 mm). For the conventional acquisition, the 124 phase encoding lines were acquired in the central k-space, and the high frequency components were zero-filled before image reconstruction, resulting in an effective in-plane resolution of 1.3 $\times$ 0.7 mm^2. In the GRAPPA acquisition, the k-space coverage was almost doubled with the same number of acquired lines, increasing the spatial resolution by a factor of 2. The imaging time was the same for the two acquisitions.

Image Quality Analysis

Paired images with conventional reconstruction and with GRAPPA were presented to two of the authors, and were visually graded according to the delineation of vessel. Scoring was based on a 4-point scale: 1) poor (markedly blurred), 2) fair (moderately blurred), 3) good (mildly blurred), 4) excellent (sharply defined). Image quality was also evaluated quantitatively by measuring SNR, vessel sharpness, and vessel diameter (3). A two-tailed t-test was used to evaluate the difference between the two data sets. A P value of 0.05 or less was considered to show statistical differences.

Results

The images reconstructed by GRAPPA with accelerated sampling showed significantly higher visual rating in delineating vessels than those with conventional sampling (Table 1). Mean SNR was decreased by 36% with accelerated sampling, while mean sharpness of the vessels was increased by 24%. GRAPPA with the accelerated sampling did not change the diameter of vessel. Figure 1 shows two RCA images acquired with conventional reconstruction (Fig. 1a) and with GRAPPA (Fig. 1b). GRAPPA image delineates the vessels more sharply.

Table 1. Qualitative and quantitative comparisons of two data sets generated by conventional reconstruction and GRAPPA under the same imaging time

	Visual Rating	Mean SNR	Sharpness (1/mm)	Diameter (mm)
Conventional Reconstruction	2.9$\pm$0.5	12.0$\pm$1.9	0.79$\pm$0.077	2.7$\pm$0.6
GRAPPA	3.7$\pm$0.5*	7.7$\pm$1.2*	0.98$\pm$0.11*	2.5$\pm$0.5

*P < 0.05, indicating significant differences.

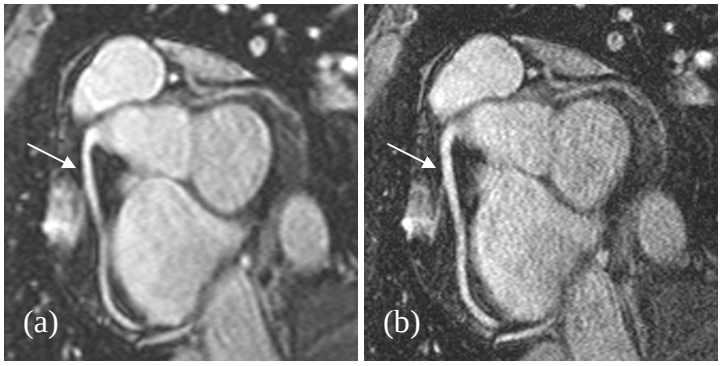

Fig. 1. RCA images generated by: (a) conventional reconstruction and (b) GRAPPA (acceleration factor = 2). Note the increased sharpness of the vessel in (b) (arrows). The imaging time was the same for the two scans.

Discussion and Conclusions

Coronary arteries have been successfully delineated by GRAPPA with an acceleration factor of 2. GRAPPA images improved in-plane resolution and showed higher sharpness of the vessels than conventional sampling under the same imaging time, though SNR loss was observed. In conclusion, GRAPPA is promising for high-resolution breath-hold coronary MRA. Higher acceleration factors may be feasible at 3T due to significant SNR gain.

References

(1) Deshpande et. al, MRM 46: 494-502 (2001). (2) Griswold et. al, MRM 47:1202-1210 (2002).
(3) Steven et. al, JMRI 13 :301-307 (2001).