SSFP Coronary MRA at 3T: Combining Extended Cardiac Data Acquisition with Parallel Imaging for High Spatial Resolution without Motion Artifacts

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Introduction: Coronary artery data have been acquired during mid-diastole to avoid cardiac motion. Data acquisition window has to be shortened, resulting in decreased acquisition efficiency and limited spatial resolution. Parallel imaging may relieve the limited spatial resolution, but requires highly accurate coil sensitivity. In addition, parallel imaging is susceptible to severe signal loss and noise amplification at high acceleration. In this work, to increase data acquisition efficiency with reduced motion artifacts and overcome the disadvantages of parallel imaging in coronary artery imaging, we propose a new way of combining extended data acquisition with regularized parallel imaging reconstruction.

Theory and Methods: A schematic of extended data acquisition with view ordering is shown in Fig. 1. A steady state free precession (SSFP) was used. Accelerated data (reduction factor (R) =3) were acquired with a short data acquisition window (~ 90 ms) in the 2nd imaging frame, while missing low frequency lines were collected in the1st and 3rd imaging frames for external calibration data (Fig. 1a). For coil calibration, internal accelerated data was combined with external calibration data within a certain frequency. Coil sensitivity was calculated using the combined k-space as (1). To reduce k-space signal discontinuity in the central region of combined k-space due to SSFP signal transition, phase encoding (PE) lines were acquired from the high to low frequencies in the 1st imaging frame (Fig. 1b), but from the low to high frequencies in the 2nd and 3rd imaging frames (Figs. 1c, 1d). The accelerated data with R of 3 was reconstructed by parallel imaging (1). To reduce noise in parallel imaging at high acceleration, tikhonov regularization (3) was used.

Coronary artery data were acquired in five volunteers using 3D segmented breath-hold SSFP sequence on a 3.0T whole body MR scanner (MAGNETOM Trio, Siemens Medical Solutions, Erlangen, Germany). Data acquisition was preceded by a spectrally selective fat saturation pulse and eight dummy radio frequency (RF) pulses with sinusoidally varying flip angles (4) for smooth transition to steady state. To demonstrate the effectiveness of the proposed technique, three data sets were acquired from each volunteer during the same imaging time using: 1) conventional acquisition with a short acquisition window (matrix=140x448, 35 lines/heartbeat (HB), 2) conventional acquisition with an extended window (matrix=300x448, 75 lines/HB), and 3) the proposed acquisition (matrix=40x448 and 10 lines/HB for the 1st and 3rd frames, respectively, matrix=100x448, R=3, and 25 lines/HB for the 2nd frame). The common imaging parameters were: TR/TE/flip angle = 3.6ms/1.8ms/50°, FOV=250 x 350mm², number of partitions=6 (interpolated to 12), and slice thickness=3mm (interpolated to 1.5mm).

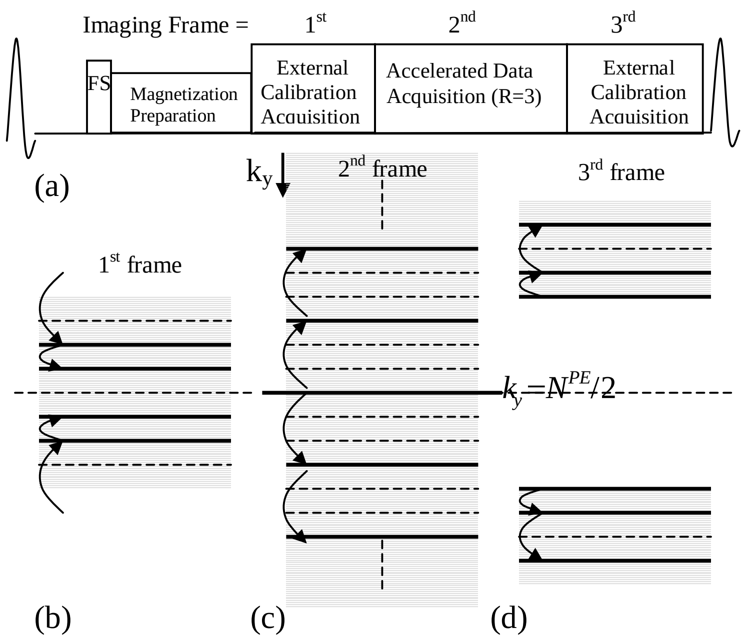

Fig.1. A schematic of extended data acquisition (a) with view ordering (b-d) (solid: measured line, dot: missing line, FS: frequency selective fat saturation pulse, k_y: PE index, N^{PE}: total number of PE lines).

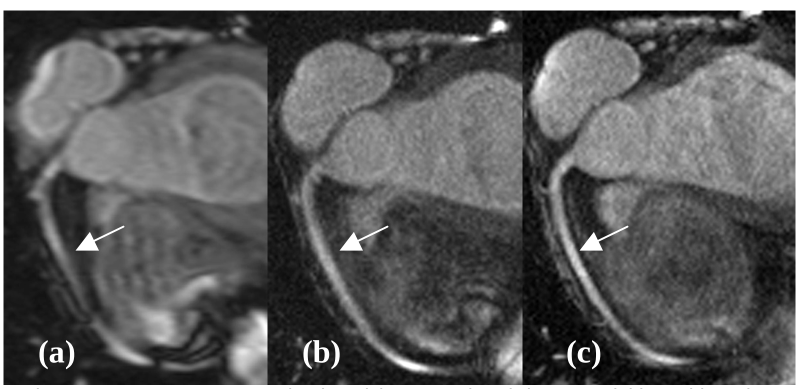

Fig. 2. Images reconstructed using: (a) conventional data acquisition with a short window (=126ms), (b) conventional data acquisition with an extended window (=270ms), and (c) the proposed data acquisition with parallel imaging reconstruction, Note low spatial resolution in (a), vessel blurring in (b), and enhanced spatial resolution without image blurring in (c).

Results: Conventional acquisition with short acquisition window yields low spatial resolution (Fig. 2a). Extending data acquisition window increases spatial resolution, but results in vessel blurring due to cardiac motion (Fig. 2b). The proposed extended data acquisition combined with parallel imaging reconstruction (R=3) enhances spatial resolution with reduced image blurring (Fig. 2c).

Discussion: The proposed extended data acquisition scheme combined with parallel imaging was successfully performed with enhanced spatial resolution and reduced motion artifacts, compared with conventional extended data acquisition. Internal accelerated data are included in coil calibration, relieving the motion mismatch problem between coil and cardiac position in conventional external coil calibration (1). To relieve the motion-induced image blurring in the conventional extended acquisition, the proposed scheme employs only the accelerated data (acquired in 90ms) in image reconstruction, while the external calibration data are used only in calculating coil sensitivity. The proposed scheme demonstrates a new way of extending data acquisition window in coronary artery imaging with nearly no motion artifacts using parallel imaging. Further investigation is needed for technical improvement and evaluation.

References: 1. Pruessmann KP, et al. MRM 42: 952-962,1999, 2. Bieril O, et al. ISMRM, 104, 2004, 3. Hansen PC. Philadelphia: Siam, 69, 1998, 4. D. Paul, et al. ISMRM, 2663, 2004