Refined Balanced Steady-State Free Precession in Breath-hold Coronary MRA at 3.0T

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INTRODUCTION: Transient balanced steady-state free precession (bSSFP) is the sequence of choice in non-contrast enhanced coronary MRA at 1.5T because of its intrinsically high blood signal and blood-myocardium contrast compared to non-balanced sequences[1]. Earlier studies of bSSFP at 3.0T report dark bands, degraded image quality, shorter visible vessel lengths, and elevated inter-observer variability compared to spoiled gradient echo sequences at 3.0T[2]. In a recent study, localized RF and B_0 shimming provided reproducible bSSFP acquisitions for imaging the major coronary arteries in a breath-hold at 3.0T[3]. **In this work,** we propose to refine the breath-hold sequence in ref. 3 with modifications that were previously proposed for acquisitions with respiratory navigators[4]: 1) shortened RF pulses using variable-rate selective excitation[5] (VERSE) to reduce both TR and acquisition time (Fig. 1B), 2) pre-saturation of dark band areas, and 3) improved transition to steady state.

METHODS: A 3D volume-targeted bSSFP sequence was optimized on a 3.0T MR scanner (Philips Achieva TX, Best, The Netherlands). An axial B_1+ map was acquired for localized RF shimming and a B_0 map was acquired along the 3D track of the coronary of interest to determine the localized 2nd order shim and resonance frequency[6]. Coronary MRA acquisitions were performed using the original[3] and the proposed sequence (Fig. 1A). Five binomial pre-saturation (BIPS) pulses were used to saturate the spins at frequencies where dark bands occur. The transition to steady state prior to acquisition was accelerated with a Kaiser-Bessel shaped flip angle sweep of 10 startup RF pulses[7]. This preparation scheme has previously been reported to suppress artifacts originating from the dark band frequencies[4]. In initial studies, the spectrally selective fat saturation (fat sat) excitation angle was optimized over the range of 80-140° for an improved fat suppression and less sensitivity to TR and field inhomogeneities. VERSE pulses[5] (Fig. 1B) were implemented reducing the TR from 3.9ms to 3.2ms. Other parameters were: TE=1.5ms, α=50°, FOV=300×300×22mm^3, voxel size=1.1×1.1×2.4mm^3, acquisition window 95ms, half-Fourier factor 0.6, SENSE 2.5 in phase-encode direction. The data were acquired during 21±1 s breath-holds. Three healthy volunteers (44-52 years old) and one patient (76 years old) with coronary artery disease were scanned. Analysis was performed using the semi-automated Soap-Bubble tool[8].

RESULTS AND DISCUSSION: All volunteers successfully completed the scans. The experimentally optimized fat sat angle was 95°. Images of the left anterior descending artery (LAD) and the right coronary artery (RCA) are shown in Figs. 2 and 3. The BIPS pre-saturation, Kaiser-Bessel startup sweep, and shorter TR due to VERSE achieved a better suppression of artifacts as highlighted by the white arrows. The visualized vessel length and vessel sharpness compared favorably for the proposed method at 104.1mm and 51% with the conventional sequence at 92.5mm and 49%, respectively.

CONCLUSION: The refined sequence in combination with RF and B_0 shimming demonstrates image quality improvements in breath-hold bSSFP coronary MRA at 3T and warrants further investigation.

REFERENCES: [1] *Invest Radiol*'02; 37:637-647. [2] *RoFo*'04; 176:1560-1565. [3] *JCMR*'13; 15(s1):E11. [4] *Proc ISMRM*'06; 370. [5] JMR'88; 78: 440-458. [6] *MRM*'04; 51:799-806. [7] JMR'03; 163:23-37 [8]. MRM'02; 48:658-666.

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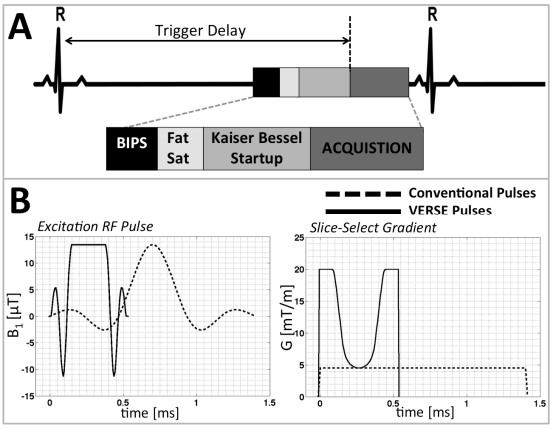

Fig. 1: *(A) The proposed transient bSSFP sequence. Magnetization is prepared with a 5-pulse binomial pre-saturation (BIPS), fat saturation, and Kaiser-Bessel shaped flip angle sweep. (B) RF and gradient pulses with standard and VERSE designs for demonstration.*

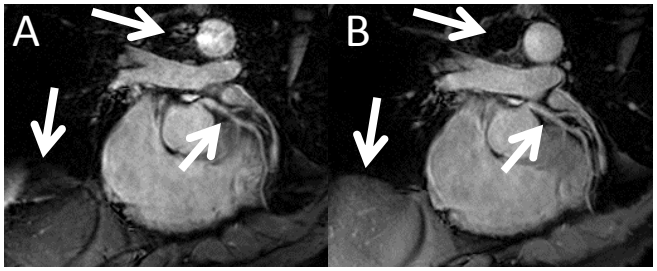

Fig. 2: *Multi-planar reformatted images of LAD in a healthy volunteer, acquired with (A) the conventional α/2-TR/2 startup without VERSE and (B) the proposed combination of BIPS, Kaiser-Bessel sweep up, and VERSE. Arrows indicate areas of improvement.*

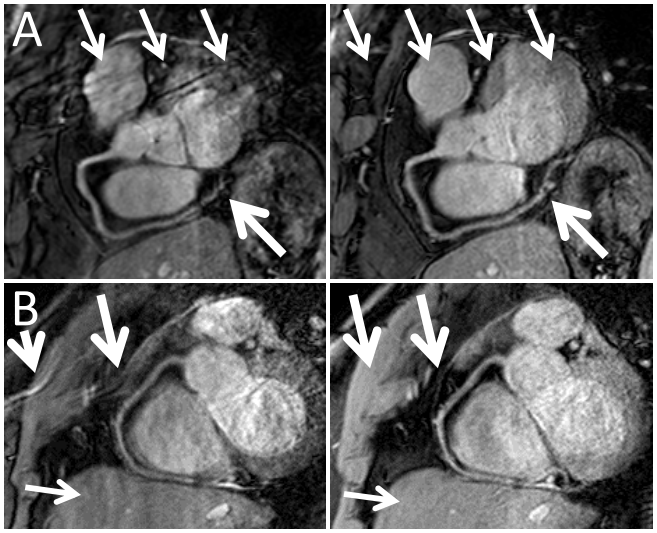

Fig. 3: *Multi-planar reformatted RCA images acquired in a single breath-hold using (left) the conventional α/2-TR/2 startup vs. (right) the proposed combination of BIPS, Kaiser-Bessel sweep, and VERSE in (A) a patient with no significant stenosis in the proximal-mid RCA and (B) a healthy volunteer. Arrows show areas of improvement.*