Tailoring Transient Balanced Gradient Echo Coronary MRA at 3.0T

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Introduction:

Balanced steady-state free precession sequences have shown great potential for coronary angiography at 1.5T (1, 2). This sequence type will be referred to as transient balanced gradient echo (tbGE) sequence to emphasize that the acquisition in coronary imaging is performed during a transient rather than in steady-state. Increased inhomogeneities of the static magnetic field B_0 and of the radio frequency field B_1 at 3.0T compared to 1.5T, together with power deposition limitations necessitate adaptations of the sequence to suppress off-resonance and flow related artifacts whilst keeping the excellent contrast.

Simulations have shown that a flip angle sweep (3) according to a Kaiser-Bessel function (4) in conjunction with a fifth-order binomial pulse to pre-saturate the darkband resonances (5) is the favored startup scheme as it provides most homogenous excitation across the off-resonance range encountered while suppressing artifacts originating from darkband resonances (6). This scheme, called BIPS5, and several other sequence adaptations were implemented to compensate adverse effects at the higher B_0.

Subjects and Methods:

The BIPS5 scheme was implemented together with variable-rate selective excitation (VERSE) (7) pulses to shorten pulse duration (and therefore repetition time TR) and/or to reduce the specific absorption rate (SAR) to comply with power deposition limitations. To compensate for B_1 inhomogeneities adiabatic echo pulses were used in the T2-preparation scheme (8). Phase-encode steps were paired to reduce flow-related phase perturbations (9). Furthermore, the fat suppression scheme, consisting of two frequency selective pulses, one before the navigator and one before the magnetization startup, was adjusted to be less sensitive to the chosen repetition time and to B_0 and B_1 field inhomogeneities. The optimized flip angles are 70° and 140° for the first and the second fat saturation pulses, respectively. Figure 1 shows the sequence setup together with simulated behavior of the magnetization of blood, myocardium and fat in a pseudo steady-state, where myocardium and fat have seen five cycles of the sequence, whereas blood only experienced two to account for inflow.

After localized shimming and resonance frequency determination based on a measured B_0-map (10), coronary MR angiograms were acquired in healthy volunteers on a clinical Philips 3.0T XMR Achieva system (Philips, Best, The Netherlands). Free-breathing, navigator-corrected, 3D angiograms of the right coronary artery (RCA) were measured with two different sequences: first, a tbGE sequence with the BIPS5 scheme with the sequence adaptations described above, and secondly a tbGE sequence with the conventional alpha-half-TR-half (AH) startup (11) and conventional sinc-Gaussian shaped excitation pulses. In the AH sequence the repetition time TR was 6.5ms and in the BIPS5 sequence 5.1ms. Both startup schemes were applied with 10 dummy excitations. The acquisition flip angle was 90°. Other parameters were: FOV = 257x300mm^2, matrix = 304x299 reconstructed to 512x512, 10 slices (3mm) reconstructed to 20 slices (1.5mm), vector-ecg triggered to the mid-diastolic rest-period as determined with the FREEZE tool from an axial cine acquisition.

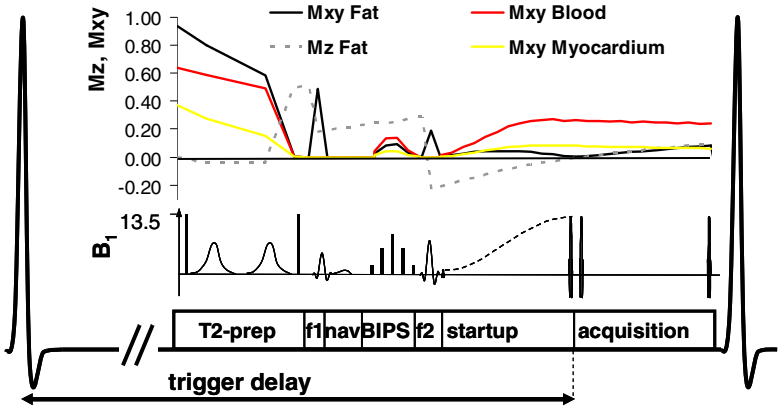

Figure 1: *Sequence setup for a transient balanced gradient echo coronary MRA at 3.0T, showing the timing with the applied radio frequency field B_1. The timing is set for the acquisition to start after a given trigger delay. Before, the magnetization is prepared with T2-preparation (T2-prep), a first frequency selective fat saturation pulse (f1), a navigator echo (nav), a five pulse binomial pre-saturation pulse (BIPS), a second fat saturation pulse (f2), and a Kaiser-Bessel shaped flip angle sweep. On top, the simulated transversal (Mxy) and longitudinal (Mz) magnetization for fat, blood and myocardium is shown in a pseudo steady-state.*

Results:

The simulated magnetization predicts excellent fat suppression with a high blood-myocardium contrast (Figure 1). Figure 2 shows images of example coronary MRAs. The application of the BIPS5 startup scheme (Figure 2A) allowed suppression of artifacts (white arrows) which are more prominent in the images acquired with the conventional AH scheme (Figure 2B). Simultaneously, both a significantly improved visual delineation and contrast in the area of the proximal coronary artery is obtained with BIPS5.

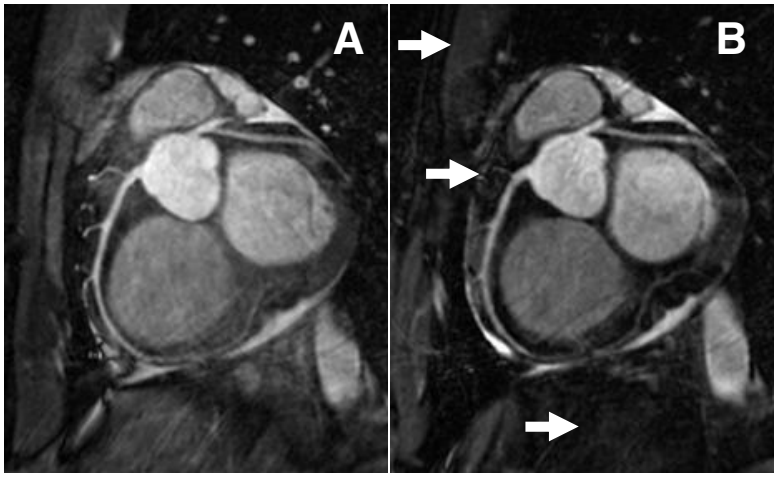

Figure 2: *Coronary angiograms acquired with transient balanced gradient echo sequences applying (A) a Kaiser-Bessel flip angle sweep in combination with binomial pre-saturation (BIPS) and (B) an alpha-half-TR-half startup. The white arrows point at artifacts due to transient signal oscillations in (B), which are suppressed when using the BIPS sequence (A).*

Discussion:

Localized shimming and frequency determination to a manually selected region of interested (ROI) on the heart is a crucial step to shift dark bands outside this ROI. Artifacts from signal oscillations stemming from dark band regions outside the ROI are then suppressed with the BIPS sequence. Changing the sequence setup made adaptations of the fat suppression necessary.

Conclusion:

The example in-vivo coronary angiograms demonstrate the effectiveness of artifact suppression when combining VERSE to shorten TR and binomial pre-saturation with a flip angle sweep as compared to the conventional AH sequence. High blood-muscle contrast was achieved with the adiabatic T2-preparation.

References:

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