Contrast Generation with a Novel Adiabatic On-Resonance Magnetization Transfer Preparation (MT-Prep)

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Target audience – Scientists and clinicians interested in using the advantageous but technically challenging MT image contrast.

Purpose – Magnetization transfer (MT) preparation provides image contrast similar to that created by T2-prep, but typically has increased robustness towards B0-inhomogeneity, cardiac motion and blood flow, making it highly desirable for cardiac MR (CMR). MT-prep may be an alternative to T2-imaging for the detection of edema in acutely injured myocardium. Venous and arterial blood has equal brightness in MT contrast images, which can be advantageous when used in combination with inversion recovery for flow-independent dark-blood preparation. Despite these advantages, MT-prep is infrequently used, because the standard MT pulses[1], which are applied off-resonance, are relatively inefficient at creating MT effect and require high energy and power. Existing on-resonance MT techniques[2] may be more efficient, but are typically based on composite rectangular pulses, which are not sufficiently robust towards B0 and B1. Therefore, we devised an efficient adiabatic on-resonance MT-prep that creates MT contrast with less energy and power than off-resonance pulses while achieving comparable blood-tissue separation. This study examines the feasibility of using this novel MT-prep in cardiac patients.

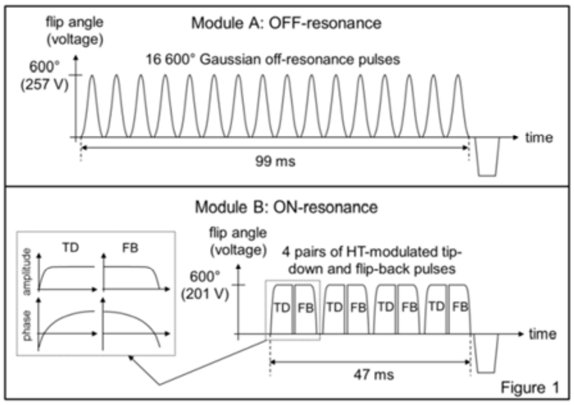
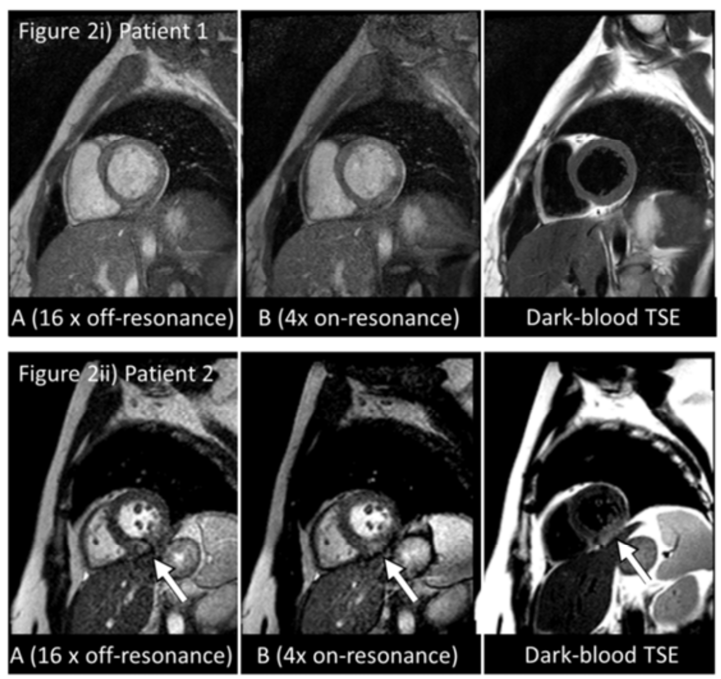


Figure 1

Methods – The study was approved by our IRB and informed consent was obtained from each patient. 10 cardiac patients (7 females, 3 males) were imaged on a MAGNETOM Avanto (1.5T, Siemens Healthcare, Erlangen, Germany). We acquired identical slice locations with identical sequence parameters (gradient echo, TE 1.5 ms, TR 4.0 ms, segments 21, fov 340x255mm, resolution 1.5 x 2.0mm, thickness 6mm, flip angle 15°, effective TR 1.6s – 2.0s), but with the two different MT preparations shown in Figure 1: A) the standard off-resonance MT- prep (16 600° Gaussian pulses 600 Hz off-resonance) and B) the novel adiabatic on-resonance MT-prep (4 modules, each consisting of a hyperbolic tangent modulated tip-down (+90°) and flip back pulse (-90°)). We measured image intensity in LV and RV blood pool and in myocardium (MYO) in the coil-sensitivity normalized images and calculated the ratios LV/RV and LV/MYO. Using a two-tailed t-test we compared the ratios between modules A and B to determine if novel module B would create the same blood-tissue contrast as A. We calculated signal-to noise ratio (SNR) in LV, RV and MYO for modules A and B as a measure of image quality. We calculated typical energy and power of A and B. Note that in novel module B the modulation function (amplitude and phase) of the flip-back (FB) pulse is time-reversed (mirrored in time) relative to the tip-down (TD) pulse. This design ensures that phase dispersion created by the TD is compensated by the FB pulse.

Results – Figure 2 shows cardiac short-axis images of two patients with (bottom row) and without (top row) acute infarction. TSE images confirm the presence of acute infarction in the lower row (white arrows). For preparations A and B, average blood-myocardium contrast was 21.25 ± 2.89 (mean ± sem) and 20.11 ± 2.66, respectively, which was statistically identical ($p > 0.05$). Average LV/RV signal ratios were also identical between A and B ($p > 0.05$) with 1.12 ± 0.02 and 1.11 ± 0.04. All pulses (A and B) used a 600° flip angle yielding an effective flip angle of ±90° for the TD and FB pulse. In a typical patient (typical weight and coil loading) the peak pulse voltage was 257V and 201V, the required total energy was 56.3 Ws and 29.8 Ws, and the duration was 99 ms and 47 ms, for A and B respectively. Thus, novel method B needed only 52.9% of A's energy and was played in about half the time. Peak pulse power of B was 61% of A. For A and B, SNR in LV blood was 52.74 ± 7.40 and 47.51 ± 6.11, and in myocardium was 31.49 ± 4.92 and 27.39 ± 3.53, respectively. Again, no significant statistical difference ($p > 0.05$) between A and B was found.



Discussion – This study shows that the presented on-resonance MT-preparation has blood-tissue contrast, image quality and SNR equivalent to the standard off-resonance approach, despite significantly reduced energy and power requirements. This opens the opportunity for using MT contrast on standard clinical MRI scanners where SAR and limited available RF energy would generally prevent establishing significant MT contrast.

Conclusion – We expect the adiabatic on-resonance MT-preparation to be useful for imaging of edema in acute infarction, creation of blood-tissue contrast in coronary angiography, and for homogeneous flow-independent dark blood preparation in combination with inversion preparation.

References – 1. Balaban, R.S., Magnetization Transfer between Water and Macromolecules in Proton MRI, in eMagRes. 2007, John Wiley & Sons, Ltd. 2. Schneider, E., R.W. Prost, and G.H. Glover, Pulsed magnetization transfer versus continuous wave irradiation for tissue contrast enhancement. Journal of Magnetic Resonance Imaging, 1993. 3(2): p. 417-423.