Dark Blood Delayed Enhancement in Humans By Double Preparation and Gradient-Echo or Turbo-Spin-Echo Readout

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Introduction: The segmented IR-TurboFlash sequence is considered the gold standard for imaging myocardial viability [1] (figure 1a), but small subendocardial infarcts are sometimes difficult to detect. As a solution we have described a dark blood delayed enhancement technique [2] that combines a slice-selective saturation (SSSR) after the R-wave with a later non-selective inversion (NSIR, 1b). When applied to patients with fast heart rates or lower contrast agent concentrations in blood and myocardium, the selective preparation can be played right after the R-wave and data readout occurs during late diastole. The imaging slice is inside the preparation slab and sufficient time for fresh "dark" blood to enter the slice is available. At lower heart rates or higher contrast concentrations, the time between the selective preparation and readout is too short to place them at the optimal time points within the cardiac cycle. Inhomogeneous imaging-slice preparation and incomplete blood exchange can result. To circumvent both problems, we replaced the SSSR with a slice-selective inversion (SSIR) pulse which allowed us to extend the time between both events. Now they occur at the optimal time points in the cardiac cycle. With this sequence we successfully imaged ten patients with infarcts confirmed by the gold standard technique.

Methods: Blood and non-infarcted myocardium can be simultaneously nulled (appear dark in the image) by a timed combination of a selective preparation right after the R-wave followed by a later non-selective inversion. The relaxation curves of blood and tissue are decoupled as the imaged blood only experiences the non-selective preparation. Figure 1 shows the relaxation curves for normal myocardium, infarct, and blood about ten minutes after IV injection of 0.125 mmol/Kg Gd-DTPA ($T1_{blood}$ = 290 ms, $T1_{normal}$ = 450, $T1_{infarct}$ = 270 ms) [3, 4] for the gold standard (1a), the SSSR-NSIR (1b), and the SSIR-NSIR technique (1c), respectively. The time from the NSIR to the center of k-space is chosen to null blood and only depends on its T1. The time between the selective preparation and the NSIR pulse is set to null normal myocardium when blood is nulled and depends on the T1 of normal myocardium, blood, and the type of selective preparation. We implemented this technique with a gradient-recalled echo (GRE) and a turbo-spin-echo (TSE) readout and imaged ten consecutive patients with confirmed myocardial infarction with both sequences on a clinical MR scanner (Magnetom Sonata, Siemens Medical Solutions). SNR and CNR (infarct to blood and to normal myocardium) were measured and compared with those of the gold standard. Typical parameters were field of view 380 x 285 mm, matrix 256 x 147, TE 3.85 ms (GRE), echo spacing 5 ms (TSE), spatial resolution 1.5 x 2.0 x 6 mm, lines per segment 21, acquisition duration 14 heartbeats.

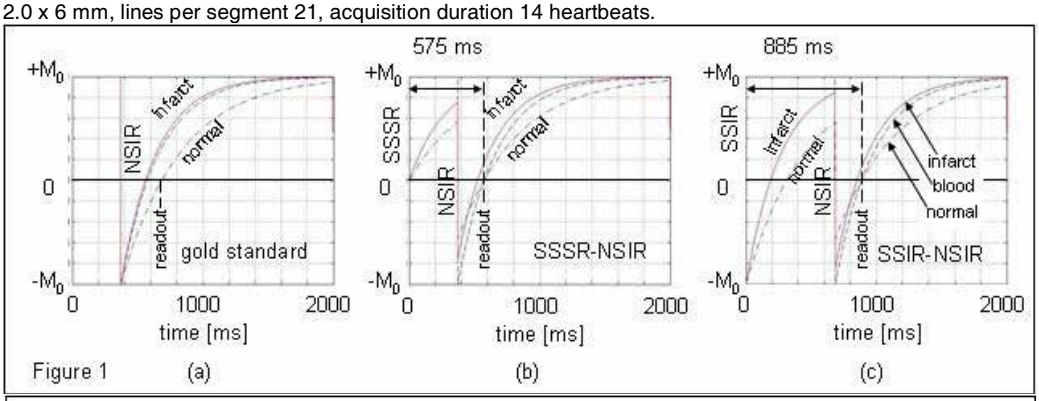

Figure 1

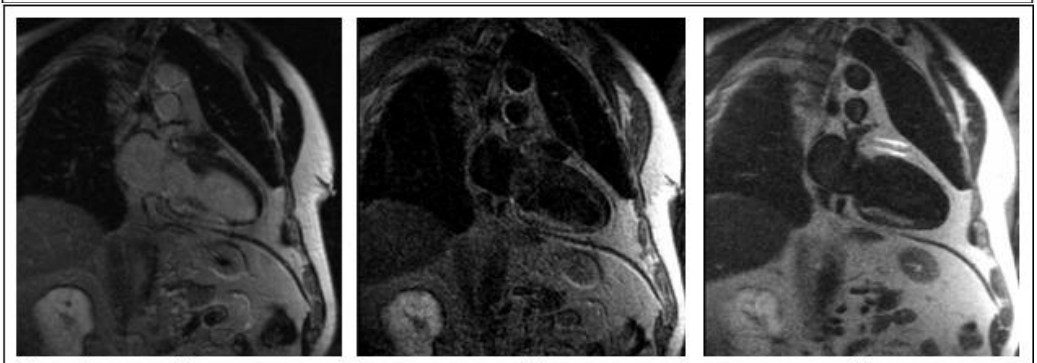
Figure 2 (a) (b) (c)

Results: Figure 1 shows that for the T1-values listed above the time between the slice-selective preparation to the center of k-space increases from 575 ms (SSSR, 1b) to 885 ms (SSIR, 1c). In the patients this time increased by 45% ± 16%. Figure 1 also shows that for these T1-values the infarct signal at the nullpoint of normal myocardium drops from 0.35M0 in the gold standard to 0.17M0 in the SSSR and further to 0.13M0 in the SSIR technique. Figure 2 shows a long-axis cardiac image acquired with the gold standard (2a), the SSIR-NSIR GRE (2b), and the SSIR-NSIR TSE sequence (2c). Infarct SNR is 16.97 in the gold standard, 12.92 in the SSIR GRE, and 14.78 in the SSIR TSE images. CNR between infarct and blood (and normal myocardium) is 1.38 (12.5) in the gold standard, 7.8 (6.35) in the SSIR GRE, and 9.84 (8.73) in the SSIR TSE images.

Conclusions: A dark blood delayed enhancement technique was developed to facilitate the visualization of small subendocardial infarcts in humans. CNR of infarct to blood is markedly improved in both the GRE and TSE version of the SSIR-NSIR method, which comes at the expense of a lower yet still large SNR and CNR of infarct to normal. For optimal timing, a SSSR preparation is favorable for faster heart rates and lower contrast agent concentrations, a SSIR preparation for slower heart rates and higher concentrations. Stretching the time between selective preparation and data readout with the SSIR preparation causes a lower infarct signal that can be partially recovered by a TSE readout.

References:

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