Preserving Signal Contrast in Multi-Slice Black Blood Fast Spin Echo

A. J. Madhuranthakam[1], J. L. Wei[2], J. H. Brittain[3], N. M. Rofsky[2], and D. C. Alsop[2]

[1]Applied Science Laboratory, GE Healthcare, Boston, MA, United States, [2]Radiology, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, United States, [3]Applied Science Laboratory, GE Healthcare, Madison, WI, United States

Introduction: Black blood T_2-weighted abdominal images are often used to assess aortic dissection and intramural hematoma (1). The commonly used black blood technique is based upon double inversion recovery (DIR) (2), in which a non-selective IR is immediately followed by a slice selective IR and then timed to null the inflowing blood to acquire that particular slice. Although this is inherently a single-slice technique, various multi-slice approaches have been proposed for efficient acquisition (3,4). Alternatively, when DIR is applied in conjunction with a single shot fast spin echo (SSFSE or HASTE), multi-slice acquisition can be performed in an efficient manner with minimal delay times between slices.

In a DIR-SSFSE sequence, the initial longitudinal magnetization (M_z) of the first slice is always maintained at its equilibrium prior to its acquisition (Fig. 1, green). However for a subsequent slice, the initial M_z varies based on the tissue T_1 recovery from the non-selective IR applied prior to the acquisition of first slice. Depending upon the null time (TI_{null}), acquisition time (T_{acq}) and the delay time (T_{delay}), most of the tissue recovers to their equilibrium (Fig. 1, blue), except for long T_1 species such as fluid (in CSF, hematoma, and liver lesions) (Fig. 1, magenta). This causes their signal to appear dark in the later slices and can cause difficulty in diagnosis due to the altered contrast. Our hypothesis is that a T_2-prep module with diffusion gradients applied prior to SSFSE can achieve black blood while preserving the signal contrast from remaining tissue at their equilibrium for all slices.

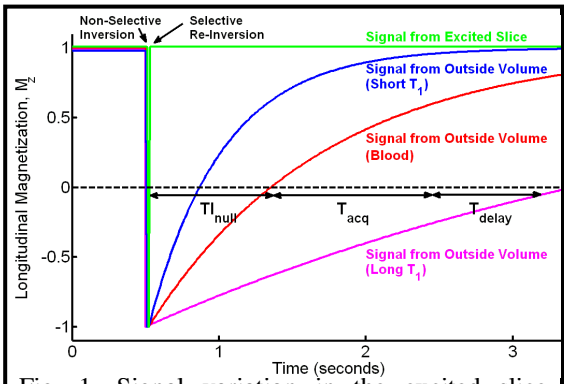

Fig. 1. Signal variation in the excited slice (green) and the outside volume following a non-selective inversion and a selective re-inversion, as applied in DIR.

Methods: A preparation module modified from a T_2-prep sequence with 90°-180°-180°-(-90°) by adding diffusion gradients (Fig. 2) (5,6) was played in front of a SSFSE sequence. All RF pulses were played as non-selective and hence the diffusion gradients affect the signal from moving tissue in the entire volume coverage of the transmit coil. At the time of the spin echo formation after the second 180°, a -90° was played to restore the magnetization towards the equilibrium. To be insensitive to B_1 inhomogeneities, adiabatic hyperbolic Secant pulses were used for the 180° refocusing pulses (7).

With IRB approval, normal volunteer abdomens were imaged using a multi-slice SSFSE sequence to test our hypothesis with emphasis on CSF signal in the spinal cord. 20 slices were acquired within a breath-hold using plethysmographic peripheral gating (PG) to synchronize data acquisition to diastolic phase. This was necessary to avoid the signal loss due to liver motion transmitted from cardiac pulsatility, because the diffusion gradients affect the signal from any moving tissue. For our preliminary studies, the diffusion gradients were empirically adjusted to achieve black blood. For comparison, a standard SSFSE and a DIR-SSFSE with PG were also acquired in separate breath-holds.

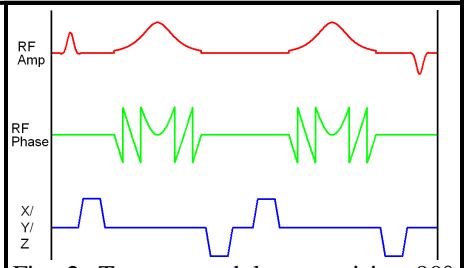

Fig. 2. T_2-prep module comprising 90°, 180°, 180°, and –90° RF pulses with diffusion gradients along X, Y and/or Z.

Results: Fig. 3 compares two different slices using all three sequences. Black blood was achieved in major vessels using both DIR-SSFSE (Fig. 3b, 3e) and T_2-prep-SSFSE (Fig. 3c, 3f), for e.g., see the aorta (arrow head). The signal and contrast of the non-vascular tissue in the first slice (Fig. 3a-3c) is comparable in all three acquisitions, while differences are seen in a slice that was acquired during 19th repetition (Fig. 3d-3f). Particularly, the CSF (arrow) appears dark with DIR-SSFSE (Fig. 3e) while it is bright in appearance using T_2-prep-SSFSE (Fig. 3f), similar to standard SSFSE (Fig. 3d). Similar contrast variation is also observed in bile ducts due to its long T_1.

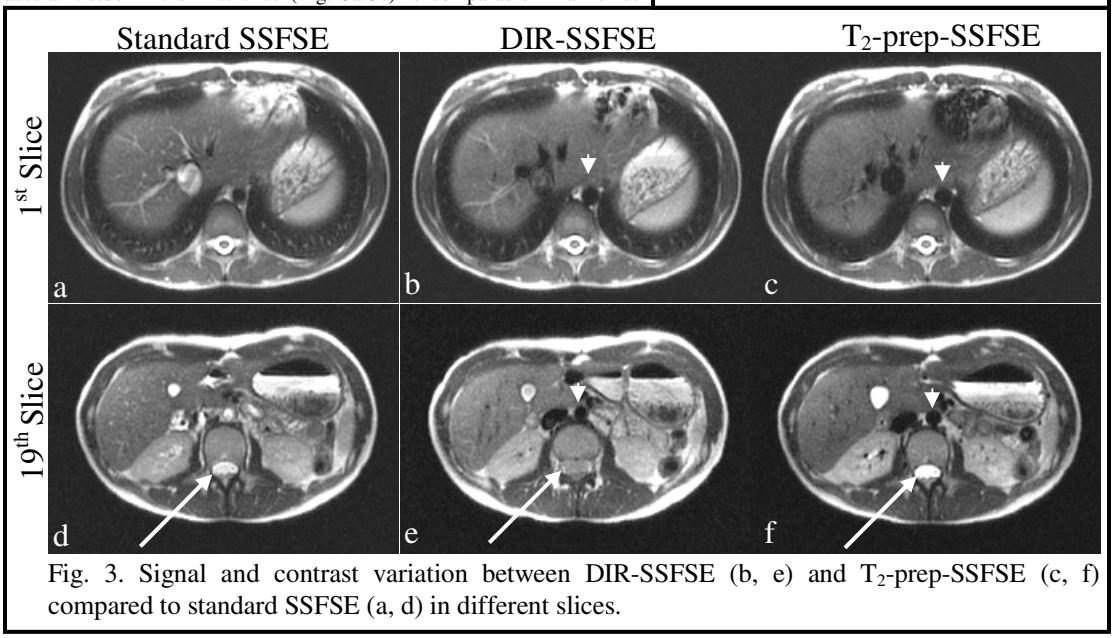

Fig. 3. Signal and contrast variation between DIR-SSFSE (b, e) and T_2-prep-SSFSE (c, f) compared to standard SSFSE (a, d) in different slices.

Discussion: While achieving black blood in a T_2-weighted image is essential to diagnose aortic dissection and intramural hematoma, it is also important to preserve the contrast of long T_1 structures in all slices for proper diagnosis. We presented such a sequence using a T_2-prep module using diffusion gradients. Since the diffusion gradients affect the signal from any moving tissue, extra care needs to be taken to account for cardiac and respiratory induced motion. Additionally, DIR-SSFSE achieves black blood based upon through plane flow, which is well suited for axial acquisitions but T_2-prep-SSFSE can be used to achieve black blood flowing in different orientations (see vena cava in Figs. 3b, 3c) by using appropriate diffusion gradients.

Reference: 1) Stemerman et. al. Radiology 99; 213: 185 2) Edelman et. al. Radiology 91; 181: p. 655. 3) Song et. al. MRM 02; 47: p. 616. 4) Yarnykh et. al. JMRI 03; 17: p. 478. 5) Koktzoglou et. al. JCMR 07; 9: 33. 6) Nguyen et. al. JMRI 08; 28: 1092. 7) Nezafat et. al. MRM 06; 55: 858.