MP-SWIFT with adiabatic inversion preparation for quiet, B_1 insensitive T_1 weighted imaging.

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Introduction: SWIFT(*1*) (SWeep Imaging with Fourier Transform) is a radial imaging sequence utilizing gapped frequency-swept pulse excitation(*2*) and nearly simultaneous signal acquisition in the gaps between pulse elements. Because acquisition occurs "inside" the gapped pulse, SWIFT has an intrinsically short dead-time, at present hardware-limited to ~3-15 μs. This provides sensitivity to very fast relaxing spins, similar to that achieved by UTE (Ultra-short TE) sequences.

In this work we add a magnetization preparation (MP) segment interleaved with views of the SWIFT readout, in a manner analogous to MP-RAGE(*3*). We show high-resolution clinical-quality proton-density and adiabatic inversion magnetization prepared T_1-weighted images at 62.5 kHz bandwidth in human brain for the first time with MP-SWIFT.

Experimental Methods: We implemented MP-SWIFT on our 4 T research MRI scanner (Oxford 90 cm bore magnet, Siemens Sonata 4 gauss/cm gradients, Varian Inova console, vnmrj "classic" interface). MP-SWIFT utilizes an adiabatic HS4 R10 pulse(*4*) for inversion preparation followed by a gapped HS1 based SWIFT readout. The adiabatic inversion preparation is inserted every 256 spoke views of the SWIFT readout (total 96,000 radial k-space spokes). For the head imaging we utilized a custom "long" quadrature input-output TEM circularly polarized transceive head coil (TEM head coil(*5*)) which has very low short T_2 background signal. The SWIFT imaging sequence is currently limited at 4 T to 62.5 kHz bandwidth when using the TEM head coil, due to ring-down and B_1 performance trade-offs. For optimal SNR and ring-down elimination we use an in-house engineered Echotek digital receiver(*6*).

Results: We show in the Figure(s) a representative unfiltered slice from SWIFT (A), MP-SWIFT (B), and the MP-SWIFT / SWIFT (C) ratio of a normal adult human head. While these images all contain short T_2 signal, the contrast is dominated by longer T_2 signal. Figure A consists of a standard 2° flip, 62.5 kHz, TR=4.9ms, 8-minute, 96,000 unique radial fid view (spoke) SWIFT dataset reconstructed to 256x265x256 isotropic nominal resolution by in-house gridding software. Figure B consists of the same nominal slice with MP-SWIFT, TI=1.1 s and no additional recovery time other than 256 views of SWIFT readout (about 1.25 s), with imaging time of 14 minutes. All other parameters were the same. Figure C is the ratio MP-SWIFT/SWIFT which removes all intensity variations due to the SWIFT readout as well as B_1 variations, a highly desirable property at very high field. The ratio technique was first demonstrated with a MP-RAGE/RAGE ratio(*7*).

An important result is that the SWIFT sequence is 50dB quieter than 3D Cartesian T_1-weighted FLASH of similar bandwidth on our 4 T scanner. Absolute sound intensity is 55dBb (normal conversation is ~70 dB) compared to 104dB for FLASH. No ear protection is necessary with a SWIFT-only MRI session. The MP-SWIFT preparation adds some noise; however, the gradient ramping can be made smoother since the timing is not critical.

Discussion: Unlike RAGE, SWIFT performs excitation simultaneously with acquisition. This favors the choice of preparations which leave the magnetization in the longitudinal state. Other standard preparation-excitation combinations can be used with a flip-back. We anticipate that SWIFT and MP-SWIFT will have several immediate applications in imaging of pediatric and phobic patients.

In conclusion, we present 4 T head imaging with MP-SWIFT for T_1 contrast and plan further exploration of other contrast mechanisms, applications desiring quiet operation such as pediatric imaging, and other applications where fast and quiet imaging is required.

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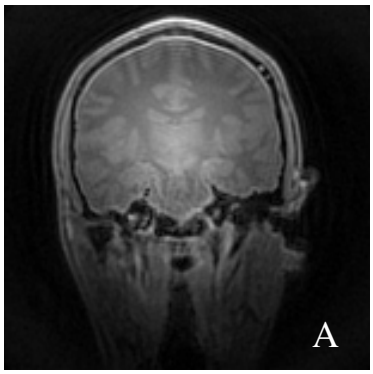

Figure A: SWIFT 3d isotropic 256^3 8 min. 62.5 kHz bandwidth. Dead time ~3-5 μs. TR is 4.9 ms. Flip angle is 2°.

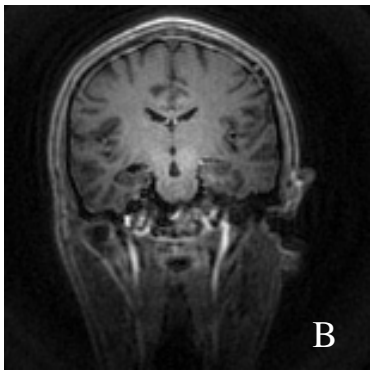

Figure B: MP-SWIFT 3d isotropic 14 min. Preparation is adiabatic inversion recovery. TI (tau) is 1.1 s every 256 SWIFT views.

Figure C: Ratio Image, MP-SWIFT/SWIFT Contrast is entirely determined by preparation. B_1 effects on contrast and intensity are removed.

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