Fast, low SAR and off-resonance insensitive T2 weighted Variable Amplitude PSIF (T2 VAPSIF) imaging
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Introduction: T2-TIDE (Transition into Driven Equilibrium) [1] is a balanced SSFP (b-SSFP) sequence with a T2w transient acquisition. In this technique, the center of k-space is sampled using a spin-echo scheme (90°-180°-180°-…), to achieve T2w. While traversing towards the outer k-space lines, the flip angle is ramped down which reduces SAR, preserves signal and maintains edge resolution compared to Half Fourier Acquisition Single shot Turbo spin Echo (HASTE). However, T2-TIDE is sensitive to B0 inhomogeneities, especially at high and ultra-high fields (>3T). In this work, we present a sequence called T2w Variable Amplitude PSIF (T2 VAPSIF) which exhibits reduced SAR, good edge resolution and T2w, but is also insensitive to B0 inhomogeneities.

Methods: Based on T2-TIDE, T2 VAPSIF incorporates a Kaiser-Bessel preparation module for transient signal stabilization and employs a PSIF acquisition scheme for reduced B0 inhomogeneity sensitivity. The flip angle scheme thus consists of four blocks: i) Kaiser-Bessel (KB) stabilization pulses ii) 180° pulses iii) Ramp pulses and iv) PSIF (α) pulses. Partial fourier fraction (PF) is used to adjust the effective TE (TEeff), thereby controlling the amount of T2w. The outer +k-space is acquired with PSIF as shown in Fig.1. MATLAB simulations were performed for T2-TIDE and T2 VAPSIF for 6 different tissues with T1/T2 values (500/50, 500/60, 500/200, 2400/50, 2400/60, 2400/200 ms). Simulation parameters were #180: 25, #Ramp: 10, α: 70°, TR: 5.2 ms and off-resonance dephasing of -π to +π (steps of π/18). Phantom Imaging: All imaging was performed on a 3T MRI scanner (Siemens MAGNETOM Tim Trio). T2 phantoms were prepared with different concentrations of MnCl2. 2D single slice TSE, HASTE, b-SSFP, T2-TIDE and T2 VAPSIF images were acquired with similar spatial resolutions. T2w images were acquired with TEeff of 103ms and PF: 0.57. Volunteer Imaging: 2D single slice abdominal imaging was performed in two volunteers using respiratory triggered TSE (TEeff: 90ms) and HASTE, T2-TIDE and T2 VAPSIF (TEeff: 180ms, PF: 0.69). An extra gradient of 50µT/m was applied along the read direction to induce B0 inhomogeneities during T2-TIDE and T2 VAPSIF acquisitions.

Results: Simulation results of T2-TIDE and T2 VAPSIF (Fig 2) show that a) the initial 180° pulses result in pure T2 decay which are ramped down to the SSFP/PSIF acquisition achieving a steady-state signal level and b) T2 VAPSIF is insensitive to off-resonance related artifacts. Fig. 3 shows images of the phantom acquired using different sequences. Banding artifacts are visible in both b-SSFP (Fig.3c) and T2-TIDE (Fig.3d) (solid arrows) images, but not in T2 VAPSIF (Fig.3f) images. T2 VAPSIF also demonstrates comparable T2w to TSE and HASTE, with sharper edges than HASTE. Energy deposition of T2-TIDE and T2 VAPSIF was reduced by a factor of 2 compared to HASTE. Volunteer images of T2-TIDE (Fig.4c) show banding artifacts due to the extra gradient (white arrows), which are not seen with T2 VAPSIF (Fig.4d). T2 VAPSIF showed comparable T2w to TSE (Fig.4a) and HASTE (Fig.4b). Similar energy deposition was observed for both T2-TIDE and T2 VAPSIF compared to HASTE but with a 1.5 factor reduction in acquisition duration.

Conclusion: T2 VAPSIF is a promising sequence for fast, low SAR, T2w imaging that is insensitive to B0 inhomogeneities and capable of good edge resolution.