Fast, low SAR and off-resonance insensitive T2 weighted Variable Amplitude PSIF (T2 VAPSIF) imaging

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Introduction: T_2-TIDE (Transition into Driven Equilibrium) [1] is a balanced SSFP (b-SSFP) sequence with a T_2w transient acquisition. In this technique, the center of k-space is sampled using a spin-echo scheme (90^0-180^0-180^0-…), to achieve T_2w. 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, T_2-TIDE is sensitive to B_0 inhomogeneities, especially at high and ultra-high fields (>3T). In this work, we present a sequence called T_2w Variable Amplitude PSIF (T_2VAPSIF) which exhibits reduced SAR, good edge resolution and T_2w, but is also insensitive to B_0 inhomogeneities.

Methods: Based on T_2TIDE, T_2VAPSIF incorporates a Kaiser-Bessel preparation module for transient signal stabilization and employs a PSIF acquisition scheme for reduced B_0 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 (TE_{eff}), thereby controlling the amount of T_2w. The outer +k-space is acquired with PSIF as shown in Fig.1. MATLAB simulations were performed for T_2TIDE and T_2VAPSIF for 6 different tissues with T_1/T_2 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). T_2 phantoms were prepared with different concentrations of $MnCl_2$. 2D single slice TSE, HASTE, b-SSFP, T_2-TIDE and T_2VAPSIF images were acquired with similar spatial resolutions. T_2w images were acquired with TE_{eff} of 103ms and PF: 0.57. ***Volunteer Imaging:*** 2D single slice abdominal imaging was performed in two volunteers using respiratory triggered TSE (TE_{eff}: 90ms) and HASTE, T_2-TIDE and T_2VAPSIF (TE_{eff}: 180ms, PF: 0.69). An extra gradient of 50μT/m was applied along the read direction to induce B_0 inhomogeneities during T_2-TIDE and T_2VAPSIF acquisitions.

Results: Simulation results of T_2-TIDE and T_2VAPSIF (Fig.2) show that a) the initial 180˚ pulses result in pure T_2 decay which are ramped down to the SSFP/PSIF acquisition achieving a steady-state signal level and b) T_2VAPSIF 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 T_2-TIDE (Fig.3d) (solid arrows) images, but not in T_2VAPSIF (Fig.3f) images. T_2VAPSIF also demonstrates comparable T_2w to TSE and HASTE, with sharper edges than HASTE. Energy deposition of T_2-TIDE and T_2VAPSIF was reduced by a factor of 2 compared to HASTE. Volunteer images of T_2TIDE (Fig.4c) show banding artifacts due to the extra gradient (white arrows), which are not seen with T_2VAPSIF (Fig.4d). T_2VAPSIF showed comparable T_2w to TSE (Fig.4a) and HASTE (Fig.4b). Similar energy deposition was observed for both T_2TIDE and T_2VAPSIF compared to HASTE but with a 1.5 factor reduction in acquisition duration.

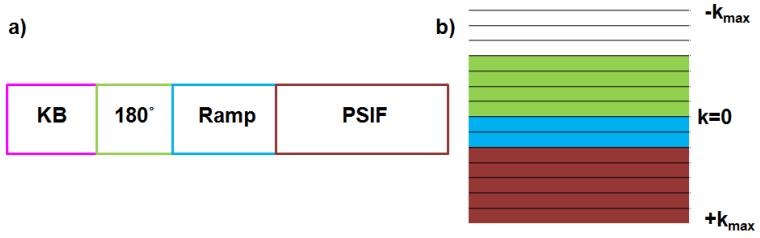

Fig. 1: *a) Block diagram showing the flip angle scheme for the T_2VAPSIF sequence b) k-space diagram showing the flip angle scheme with partial Fourier acquisition. Note: the Kaiser-Bessel (KB) block is used only for steady-state signal stabilization and no data is acquired. The 180 pulse block provides T_2w; the Ramp and PSIF pulse blocks reduce SAR and maintain SNR in outer k-space lines.*

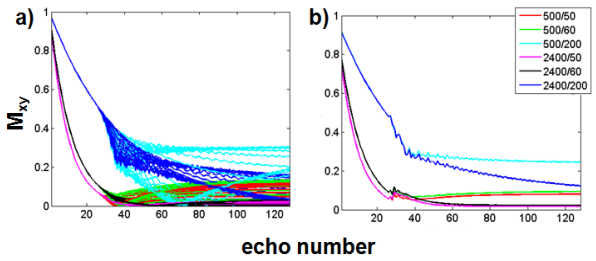

Fig. 2*: Simulation of the normalized transverse magnetization at a given echo number for a) T_2-TIDE b) T_2VAPSIF with off-resonance of -π to π. The T_1/T_2 values are shown in the legend.*

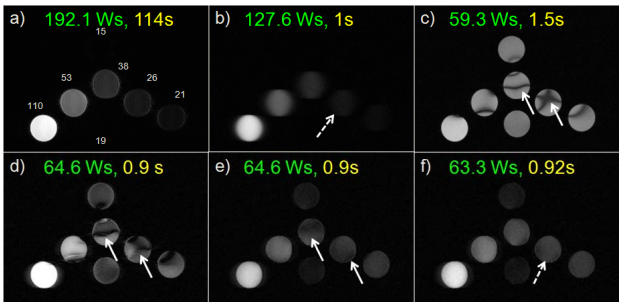

Fig. 3*: Phantom images acquired using a) TSE, b) HASTE, c) b-SSFP, d) T_2-TIDE, e) T_2TIDE PSIF with α/2 prep and f) T_2VAPSIF. The banding artifacts (solid arrows) are strong in c)-e). Edge blurring (dashed arrows) is strong in b) and less so in f). The deposited energy (green) and acquisition duration (yellow) are shown above each image.*

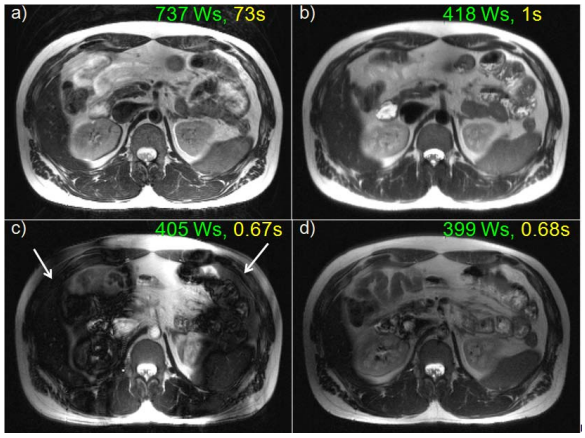

Fig. 4: *a) Respiratory-gated TSE b) HASTE c) T_2-TIDE and d) T_2VAPSIF. An additional 50 μT/m gradient was applied along the read direction during acquisition of c) and d) resulting in banding artifacts (white arrows) in c). The deposited energy and acquisition duration are shown above each image.*

Conclusion: T_2VAPSIF is a promising sequence for fast, low SAR, T_2w imaging that is insensitive to B_0 inhomogeneities and capable of good edge resolution.

Reference: 1. Paul D, et al., Proc. ISMRM **2005,** 98.