T2-weighted b-SSFP imaging using TIDE

D. Paul[1], H-P. Fautz[1], M. Markl[1], J. Leupold[1], J. Hennig[1]

[1]Dept. of Diagnostic Radiology, Medical Physics, University Hospital of Freiburg, Freiburg, Germany

Introduction

Balanced steady state free precession sequences (b-SSFP; such as TrueFISP, FIESTA, balanced FFE, …) are widely used in cardiac and abdominal imaging, typically resulting in image contrast determined by T2/T1 [1]. However, in many clinical applications a pure T2-weighted contrast is more desirable. By exploiting the signal properties of the b-SSFP transient phase a completely different contrast can be achieved [2-4]. Based on these observations, a new method (T2-TIDE) is proposed that offers T2-contrast while maintain b-SSFP advantages such as high SNR and short repetition times.

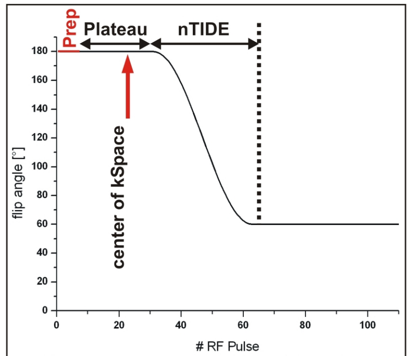

Fig. 1) flip angle scheme for T2-weighted TIDE-imaging. The central k-space is sampled after 23 pulses with high a flip angle, the outer part is sampled with low flip angles. Parameters: #Prep = 6, #Plateau = 24, #nTIDE = 32 (sinusoidal ramp)

Method

During the transient phase [2, 3], the signal decay can be described by λ [2]:

$$\lambda = e^{-T_R/T_2}\sin^2(\alpha/2) + e^{-T_R/T_1}\cos^2(\alpha/2)$$

indicating a mixture between T1 and T2 decay, weighted by the flip angle α. For high flip angles (α = 150°…180°) a nearly pure T2-weighted signal decay can be achieved. However, due to specific absorption rate (SAR) limitations the use of such high flip angles in combination with the short b-SSFP repetition times is problematic.

The proposed method is using variable flip angles in TIDE style [3]. The central part of the k-space is sampled during the initial part of the experiment with high flip angles (α_{max} =180°) in order to get the T2 decay. The outer part of the k-space is acquired using lower flip angles (α_{min} =60°) to reduce SAR. In addition, Half Fourier sampling (4/8 or 5/8) was implemented such that the k-space center is traversed during the high flip angle transient phase. As a result, contrast is determined by the high flip angles and therefore the T2-weighted signal decay [2] (T2-TIDE).

Similar to T2-TSE-sequences an effective TE, defined as the time from the first RF pulse to the acquisition of the central k-space line, was within [80,120]ms. Flexibility with respect to effective TE was achieved by changing the Half Fourier factor, matrix size, and number of preparation pulses (#Prep).

The flip angle scheme of the TIDE sequence is shown in figure 1. Parameters used for this plot are α_{max} = 180°, α_{min}=60°, #Prep=6, Number of α_{max} pulses =24, Number of TIDE pulses =32 using a sinusoidal flip angle ramp.

To estimate the T2-TIDE signal behavior, simulations with different parameters for relaxation times, flip angle scheme, and repetition time TE, were performed using Matlab (TheMathworks, Natick, USA).

All experiments (Gadolinium doped water phantoms with different T1 and T2 relaxation times and healthy volunteers) were performed on a 1.5T system (Siemens Sonata, Siemens Medical Solutions, Erlangen, Germany). Resulting images were compared to other T2-weighted imaging sequences (SE, HASTE).

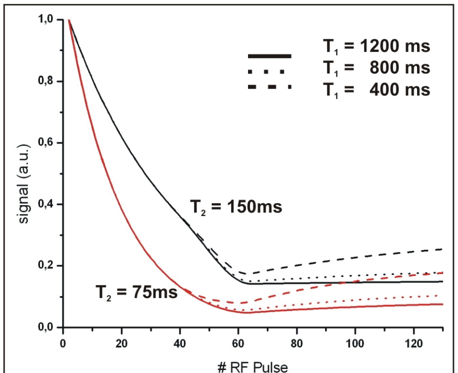

Fig. 2) Signal behavior for different T1 and T2 times for the given flip angle scheme (Fig. 1). Different T2 times are in different colors, while different T1 times are in different line shapes. The signal only depends on the T2 time during the first 40 to 50 pulses. The center of the k-space is recorded after 23 pulses with a big difference between the red and the black signal curve.

Results

Figure 2 shows simulated signal intensities for two different T2 relaxation times for the flip angle scheme of figure 1 and a TE of 4ms. As indicated by the identical signal decay for different T1 values for the first 40 to 50 rf-pulses, the signal behavior depends on T2 only during the application of the prep and plateau-pulses, and approximately the first half of the ramp. For subsequent rf-pulses the signal intensities decay to the normal b-SSFP steady state value determined by T2/T1.

Figure 3 shows phantom images using a standard TrueFISP-sequence (3a), and in comparison the T2-TIDE-sequence (3b), a T2-weighted SE- (3c) and HASTE-sequence (3d). Wile the small phantom probes (different T2 values but similar T2/T1) show almost identical signal intensities for TrueFISP, all T2-weighted sequences T2-TIDE, SE and HASTE exhibit similar and high T2 contrast between the probes. In addition, the HASTE image demonstrates blurring in probes with short T2 which is not seen in the other sequences.

Figure 4 shows abdominal axial images of a healthy volunteer for TrueFISP (4a), T2-TIDE (4b), and T2-weighted HASTE (4c). As for the phantom data, it is clearly visible that the resulting images demonstrate the same contrast for T2-TIDE and T2-HASTE, as well as better edge sharpness for T2-TIDE. In comparison the standard TrueFISP images have a different contrast. At no time the measurement exceeded SAR limits due to high flip angles.

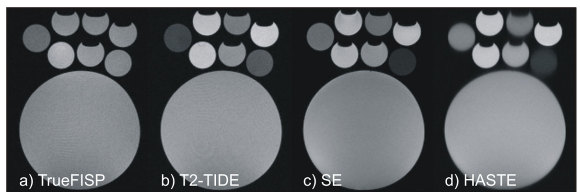

Fig. 3) Experimental measurement on Gadolinium doped water phantoms. **a)** Standard TrueFISP (TR/TE/a = 3.8ms/1.9ms/60°), **b)** T2-TIDE (TR/TE/eff. TE = 3.8ms/1.9ms/100.7ms), **c)** SE (TR/TE = 10000ms/100ms), **d)** HASTE (TR/TE = 10000ms/100ms). Relaxation times of the phantoms are in the range of T1 = 120…3000ms and T2 = 62…1500ms

Discussion

Our proposed T2-TIDE data acquisition scheme provides a robust technique to acquire T2- weighted images while exploiting advantages of b-SSFP imaging such as high signal to noise and short repetition times. It was shown that the b-SSFP signal intensity is only depending on T2 during high flip angles and part of the TIDE style ramp down. As a result, different contrast in b-SSFP-imaging can be generated, which is mainly determined by T2. For adequate effective TE a similar contrast as for T2-HASTE can be achieved with T2-TIDE. An additional advantage of T2-TIDE is found in reduced edge sharpness if compared to T2-HASTE which suffers from increased blurring due to increased T2 decay across k-space.

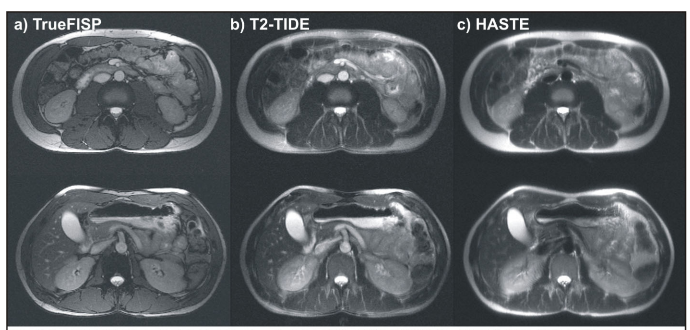

Fig. 4) Experimental measurement on a healthy volunteer. **a)** TrueFISP (TR/TE/FA = 3.7ms/1.85ms/60°), **b)** T2-TIDE (TR/TE/eff. TE = 3.7ms/1.85ms/96.2ms) **c)** T2-weighted HASTE (TR/TE = 10000ms/100ms)

References

[1] Zur Y, et al., *MRM* **6**: 175-193 (1988)
[2] Scheffler K, et al., *MRM* **49**: 781-783 (2003)
[3] Hennig J, et al., *MRM* **48**: 801-809 (2002)
[4] Huang T, et al., Proc. *ISMRM* **2003**, 984