TOSSI (T-One insensitive Steady State Imaging): Sequence optimization and first results in tumor patients

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Introduction TOSSI provides a conceptual framework for fast acquisition of images with pure T2 contrast [1]. Here, this is accomplished in practice by inserting non-equispaced inversion pulses into a TrueFISP imaging sequence, so that magnetization alternately resides in states parallel and antiparallel to Bo for durations TP and TA, respectively. With the periods TP and TA adequately chosen, T1 contrast can efficiently be removed from resultant TrueFISP images. The purpose of this paper is to give both an analytical description of ideal signal behavior and to create pathways for TOSSI sequence optimization, i.e. for the calculation of adequate TP and TA values. Furthermore, the performance of the technique is demonstrated in a study on patients with brain tumors.

Theory: After initial α/2-preparation [2], the TrueFISP signal in good approximation evolves towards the steady state signal with an apparent relaxation time T1 ∗ (derived for TR<<T1,T2 from an expression given in [3]):

\[ T_1^* = \frac{1}{T_1} \cos^2 \frac{\alpha}{2} + \frac{1}{T_2} \sin^2 \frac{\alpha}{2} \]  

(eq.1)

where α denotes the flip angle. Assuming eliminated T1 relaxation (i.e. T1→∞), a simple expression is obtained for the ideal signal time course:

\[ M_y(t) = M_0 \sin \frac{\alpha}{2} \exp(-\frac{1}{T_2} \sin^2 \frac{\alpha}{2}) \]  

(eq.2)

where M0 is spin density. Thus, the initial signal as well as the apparent decay rate depend on the flip angle. The according longitudinal magnetization component is:

\[ M_z(t) = M_0 \sin^2 \frac{\alpha}{2} \exp(-\frac{1}{T_2} \sin^2 \frac{\alpha}{2}) \]  

(eq.3)

It can be easily shown that, for a certain longitudinal magnetization M0, the optimum theoretical TP/TA ratio Ropt for cancellation of T1 relaxation influence is:

\[ R_{opt}(t) = \frac{1+M_0(t)}{t \cdot M_0(t)} \]  

(eq.4)

By inserting eq.3 into eq.4, optimized temporal schemes for subsequent times TP and TA can be found for T2 ranges of interest at a certain flip angle. In Fig1a, the ideal signal courses at α=50° are depicted for different T2 values, especially for short T2 times between 75ms and 125ms which are often encountered in the brain. The corresponding ideal Ropt values are described by functions decreasing with time. These appear to be very similar for the short T2 times, and thus an intermediate Ropt works sufficiently well for a wider range of T2 values. The ideal signal curve is well reproduced by simulated curves with optimized varying TP/TA. T2 values are separated effectively independent of their T1 and essentially pure T2 contrast is generated (Fig1b). On the other hand, the normal TrueFISP signal time course at α=50° depends on both T2 and T1 (Fig1c).

Methods: Implementations of the TOSSI concept with different timing schemes were tested on a 1.5T whole body scanner (Vision, Siemens Medical Solutions). The basis for all experiments was a standard TrueFISP sequence with TR=6.46ms. Each imaging block was prepared with an α/2-pulse. Due to software constraints, 'single shot' versions of the TOSSI sequence could only be implemented with constant TP/TA ratios. For example, a scheme with TP=241ms and TA=104ms was shown to provide artifact free T2-weighted images of the human brain with a conclusion with an -Solutions). The basis for all experiments was a standard TrueFISP sequence with TR=6.46ms. Each imaging block was prepared with an -Solutions). The basis for all experiments was a standard TrueFISP sequence with TR=6.46ms. Each imaging block was prepared with an -Solutions). The basis for all experiments was a standard TrueFISP sequence with TR=6.46ms. Each imaging block was prepared with an-

Results: In Fig2, sample images from a patient with brain metastasis are shown. Gray and white matter appear with similar intensity in the TrueFISP image (a), whereas the TOSSI image exhibits pure T2 contrast (b), very similar to the corresponding T2-weighted TSE image (c). A large metastatic tumor in the occipital white matter is visible in all images. However, the surrounding edema and a much smaller lesion in the frontoparietal white matter are hardly visible in the TrueFISP image, while both are clearly delineated in the TOSSI image, corresponding to their appearance in the T2-weighted TSE image (arrows).

Conclusion With the TOSSI concept, fast acquisition of purely T2-weighted TrueFISP images is possible. Both the initial signal and the apparent decay rate can be influenced by the choice of flip angle. In the data presented, a comparatively low flip angle of 50° was used, giving a slow decay and thus sufficient time for the acquisition of a whole image. In patients, T2-weighted images without artifacts were obtained even without the use of optimized varying TP/TA values. However, on modern scanners, further optimization of TOSSI sequences for specific applications should be feasible with the aid of the presented analytical description.

Acknowledgments Support by Siemens Medical Solutions (Erlangen, Germany) is gratefully acknowledged