Inversion-optimized, multi-slice, parallel TOSSI (T-One insensitive Steady State Imaging)

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Introduction: Pure T2 contrast can be generated in SSFP sequences using TOSSI (T-One insensitive Steady State Imaging)[1]. Non-uniformly spaced inversion pulses align the magnetization in states parallel and anti-parallel to B_0 for durations TP and TA respectively (figure 1). The physics of the magnetization's behavior and example images including those from a patient with a metastatic brain lesion have previously been presented[2]. However, initial studies were limited to non-optimal (i.e. constant) inversion timing and to single-slice acquisitions. In this study, several improvements to the TOSSI framework are presented. These improvements include better image contrast due to optimal inversion spacing, higher spatial resolution at a fixed echo time due to parallel imaging, and the ability to perform multi-slice acquisitions due to slice-selective adiabatic inversion pulses. Additionally, it is shown that TOSSI can be used to obtain rapid T2 weighted images of the head in a moving subject without the need for additional motion correction.

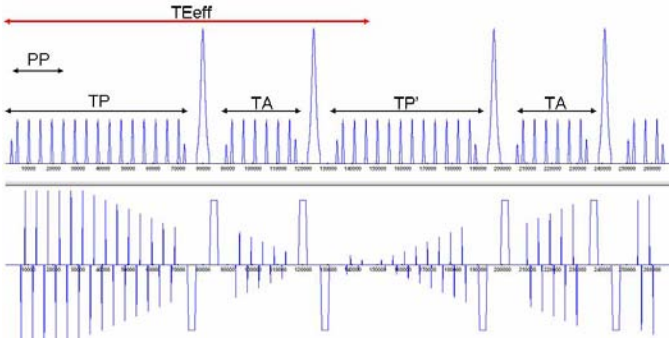

Fig. 1. RF and phase encoding gradient diagrams of the TOSSI pulse sequence. PP = prep pulses, TE_{eff} = effective echo time, TP = time in parallel state, TA = time in anti-parallel state.

Methods: An asymptomatic volunteer was placed in a 1.5 T Siemens Sonata whole body scanner after obtaining informed consent in a study approved by the local IRB. A routine 20 slice clinical T2W TSE was obtained (acquisition time: 45 sec) followed by a TOSSI sequence with the same slice positions but with interleaved slice ordering (acquisition time: 15 sec). Single-slice T2W HASTE (TE=82 msec, acquisition time: 5sec) and single-slice SE EPI (TE = 70 msec, acquisition time: 290 msec) scans were acquired for comparison. The subject then repeatedly rotated their head about the cranial-caudal axis by approximately ±45˚ at about 1 Hz during a repeat acquisition of the clinical TSE sequence and during a repeat TOSSI experiment. All studies had a spatial resolution of 0.9x0.9x5.0 mm^3 except the SE EPI which had a resolution of 1.2x1.2x5.0 mm^3. A parallel imaging acceleration factor of two using GRAPPA[3] was used for the TOSSI studies to allow TE_{eff} to be small and in order to obtain high resolution images (TSE images also had an acceleration factor of two for comparison).

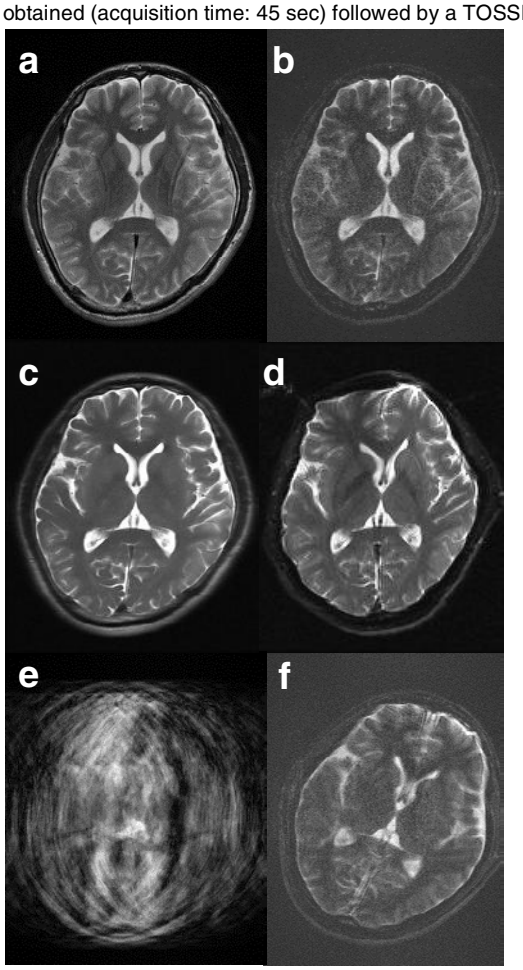

Fig. 2. **(a)** Routine clinical T2W TSE image, **(b)** single shot TOSSI image, FA = 50˚, TE_{eff} = 399 msec, **(c)** HASTE image, **(d)** SE EPI image, **(e)** motion corrupted clinical T2W TSE image, **(f)** TOSSI image during subject motion.

Results: Figure 2a shows one of the twenty T2W TSE images acquired. The fat is characteristically bright and the blood is dark. Figure 2b is an image of the same position using the new, multi-slice TOSSI sequence. Here the fat is appropriately dark (T2 of fat is ~60 msec) and blood is appropriately bright (T2 of blood is ~100-200 msec) compared to gray matter (T2 of GM is ~100 msec) and white matter (T2 of WM is ~80 msec). Note the similarity of gray matter-white matter contrast of the TOSSI image, when compared to the TSE. Both figures 2a and 2b have some minor parallel imaging artifacts. The T2W HASTE image (figure 2c) suffers from lack of GM-WM contrast. Significant geometrical distortions are seen in the SE EPI image (figure 2d). The images obtained during the subject's head motion are displayed in 2e and 2f. As can be readily seen in figure 2e the TSE image is severely degraded by resulting motion artifacts. However, the motion distortion is minimal in the TOSSI image (figure 2f) due to the short acquisition time per slice (~800 msec).

Conclusions: It is now possible to acquire fast multi-slice purely T2 weighted images of the head with improved image contrast using TOSSI. This was made possible by incorporating optimal inversion timing, slice-selective adiabatic RF pulses and parallel imaging. As was shown in previous studies[1;2], the image contrast using TOSSI is similar to clinical TSE (with the added benefit that blood and fat appear with their proper T2 weighting). It is possible with TOSSI to acquire a single slice with pure T2 weighting in ~800 msec, a much shorter time than the fastest that a single slice can be acquired with TSE (45 sec). We have exploited this ability to generate T2 contrast in a moving subject. We have shown that other methods used to generate fast T2 contrast have their own limitations: HASTE suffers from lack of GM-WM contrast while SE EPI has significant geometric distortions in the head. Therefore TOSSI can be used to generate T2 contrast in the brain in situations with unavoidable patient movement. Due to the short scan time per slice, we believe TOSSI may be an ideal way of rapidly generating T2 contrast in the brain and likely other areas and other applications including intervention.

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References: [1] P. Schmitt, P. M. Jakob, A. Haase, M. A. Griswold, *Proc.Intl.Soc. Mag.Reson.Med.* 11, #551 (2003). [2] P. Schmitt et al., *Proc.Intl.Soc. Mag.Reson.Med.* 11, #2085 (2004). [3] M. A. Griswold et al., *Magn Reson.Med.* 47, 1202-1210 (2002)