Ultra-Long Echo Trains for Rapid 3D T2-Weighted Turbo-Spin-Echo Imaging

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Synopsis: Substantially longer echo trains for turbo/fast spin-echo imaging are advantageous for decreasing acquisition time or increasing spatial resolution. We investigated whether the previously described approach of tissue-specific prescribed signal evolutions could be optimized to provide considerably longer echo trains while maintaining contrast suitable for T2W brain imaging. Theoretical results predicted that this goal was achievable for an echo-train duration of up to 1000 ms, which is 50% longer than previously demonstrated and approximately four times longer than typically used for 2D TSE/FSE imaging. This prediction was experimentally confirmed for 3D T2-weighted TSE imaging using a 250-echo, 900-ms echo train.

Introduction: Strategies for lengthening the useful duration of the echo train in turbo/fast spin-echo imaging are especially advantageous for decreasing acquisition time or increasing spatial resolution. Previous approaches for achieving this goal have included constant, low flip angles for the refocusing RF pulses [1], pseudosteady-state prescribed signal evolutions, which attained echo-train durations of up to 400 ms for 2D T2-weighted imaging [2], and tissue-specific prescribed signal evolutions, which attained echo-train durations of up to approximately 600 ms for 3D T2-weighted imaging [3]. With the aid of a theoretical model, we investigated the potential of the latter strategy for permitting further substantial increases in the echo-train duration while maintaining contrast suitable for T2-weighted brain imaging.

Methods: Using a computer-based theoretical model of turbo-spin-echo imaging implemented in C++ on a 1-GHz PC, variable flip-angle refocusing RF-pulse series and the associated signal levels were calculated for a prescribed signal evolution that was an exponential decay (relative time constant 0.175) for the first 12% of the evolution, constant for the next 42% of the evolution, and an exponential decay for the remainder (relative time constant 0.290). The effective echo time was set to the center of the prescribed signal evolution. This particular signal evolution shape has been previously demonstrated for 3D T2-weighted brain imaging [3]. Relaxation times representative of brain tissue (T1/T2 1000/100 ms) and a multiple sclerosis lesion (1300/150 ms) at 1.5 T were used to calculate the tissue signal levels, signal difference and contrast [(brain-lesion)/brain] for echo-train durations between 600 and 1200 ms and repetition times (TR) between 2500 and 5000 ms. The predicted signal difference [and thus, experimentally, (signal difference)/noise] between brain and lesion was chosen as a predictor for achieving useful T2-weighted contrast, using the signal difference corresponding to the pulse-sequence parameter set given in reference 3 as the target value.

Based on the theoretical results, variable-flip-angle series predicted to yield T2-weighted contrast acceptable for brain imaging were implemented in a 3D single-slab T2-weighted turbo-spin-echo pulse sequence. Imaging was performed on a 1.5 T whole-body scanner (Sonata, Siemens Medical Solutions). Following testing in phantoms, images of the head were acquired in a healthy volunteer after obtaining informed written consent.

Results: At constant TR, the signal levels and brain-lesion signal difference decrease with increasing echo-train duration, as would be expected. For example, at a TR of 3000 ms, the brain and lesion signals, and brain-lesion signal difference, all decrease by approximately 60% as the echo-train duration increases from 600 to 1200 ms. On the other hand, the brain-lesion contrast is approximately constant as the echo-train duration increases.

If the TR is allowed to increase with the echo-train duration, the target brain-lesion signal difference can be maintained up to echo-train durations of 900 and 1000 ms for TR limits of 4000 and 5000 ms, respectively, although the signal levels for the individual tissues still decrease with increasing echo-train duration. These trends are plotted in Figure 1.

Figure 2 shows representative T2-weighed 3D turbo-spin-echo images of the brain, acquired using an echo-train duration of 900 ms, a TR of 4000 ms, and 250 echoes. Other sequence parameters included: effective TE, 454 ms; matrix, 384 x 250 x 52 (interpolated to 104); FOV, 24.0 x 18.4 x 20.8 cm; echo spacing, 3.6 ms. The images demonstrate contrast similar to that obtained with conventional 2D T2-weighted spin-echo-based methods. The ultra-long echo train of 900-ms duration and 250 echoes permitted a complete plane of *k* space to be acquired following each excitation RF pulse in conjunction with high in-plane spatial resolution (0.6 x 0.7 mm). Contiguous 4-mm sections covering the whole head, interpolated to yield an image every 2 mm, could thus be obtained in only 3.5 minutes.

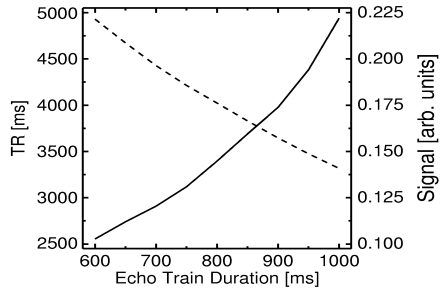

Fig. 1. Solid line: combinations of TR and echo-train duration that yield the target brain-lesion signal difference. Dashed line: the corresponding brain signal levels.

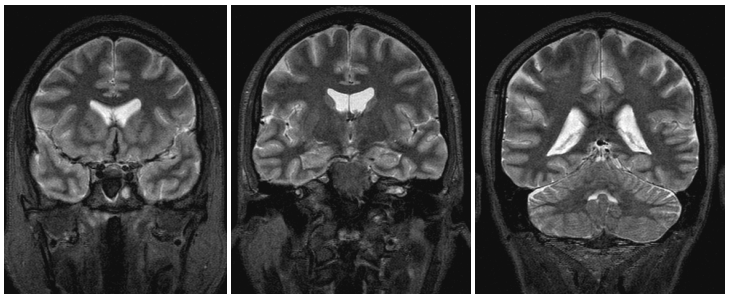

Fig. 2. Coronal T2-weighted turbo-spin-echo images of the brain from a 3D data set covering the whole head, acquired in 3.5 min.

Conclusions: For optimum combinations of echo-train duration and TR, tissue-specific prescribed signal evolutions permit 3D turbo-spin-echo images to be obtained, with contrast similar to conventional 2D T2-weighted spin-echo-based methods, using an echo-train duration of up to 1000 ms. This echo-train duration is 50% longer than that previously demonstrated for a prescribed signal evolution and approximately four times longer than that typical for 2D fast/turbo spin-echo imaging. With increasing echo-train duration the signal difference between selected tissues can be maintained, but at the expense of a decrease in signal levels. The large number of echoes that can be acquired with such an ultra-long echo train allows shorter acquisition times or higher spatial resolution. Future studies will assess the clinical appearance of brain pathologies in ultra-long echo-train images.

References: 1. Hennig J. J Magn Reson 1988; 78:397. 2. Alsop DC. Magn Reson Med 1997; 37:176.
3. Mugler JP, Kiefer B, Brookeman JR. Proc Intl Soc Mag Reson Med 8 (2000); 687.

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