Three-Dimensional T2-Weighted Imaging of the Brain Using Very Long Spin-Echo Trains

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INTRODUCTION

Spin-echo trains used in clinical fast-SE-based imaging generally employ high flip angles (>100˚) for the refocusing RF pulses. The echo-train durations are typically less than the T2s of interest for short effective-TEs or less than two to three times these T2s for long effective-TEs. For brain imaging at 1.5 T, these limits yield echo-train durations of <100 ms and <300 ms, respectively. Longer durations can degrade image contrast and cause artifacts such as blurring.

The use of low-flip-angle refocusing pulses has been proposed as a strategy for accelerating SE-train-based acquisitions by lengthening the usable duration of the echo train [1]. Alsop extended this concept by deriving variable flip-angle series based on the *pseudosteady-state* condition of a constant signal level when T1 and T2 relaxation are neglected [2]. Two-dimensional, T2-weighted brain images were acquired using an 80-echo train with a duration of 400 ms [2].

We have investigated the potential of very long SE trains based on prescribed signal evolutions which explicitly consider the T1s and T2s of interest. Using the resulting variable-flip-angle RF-pulse series, we achieved T2-weighted single-slab 3D imaging of the brain with effective-TEs and echo-train durations of greater than 300 and 600 ms, respectively.

MATERIALS AND METHODS

Using a computer-based theoretical model, variable-flip-angle refocusing RF-pulse series were calculated for several prescribed signal evolutions, including the following evolution for gray matter at 1.5 T: exponential decay for the first 20 echoes (decay constant 114 ms), constant for 66 echoes, and exponential decay for the remaining echoes (decay constant 189 ms); 160 echoes with 4.1 ms echo spacing.

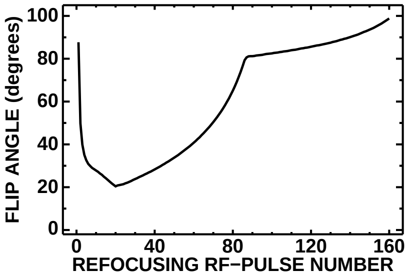
This variable-flip-angle series was implemented in a 3D single-slab T2-weighted fast-SE-based pulse sequence, adapted from previously-described techniques [3]. Imaging was performed on a 1.5 T whole-body imager (Symphony, Siemens Medical Systems). Images of the head were acquired in volunteers after obtaining informed consent. The performance of the 3D T2-weighted technique was also compared to that for a 2D T2-weighted conventional-SE sequence.

RESULTS

Figure 1 shows the calculated variable-flip-angle series for the gray matter signal evolution described above. All of the flip angles are less than 100˚, introducing a strong T1 dependence which can thereby lengthen the usable duration of the echo train substantially beyond the T2 value (~100 ms).

Figure 2 compares T2-weighted 2D and 3D images from a 59 year-old subject with age-related non-specific white-matter lesions. The very long SE-train images (Figs. 2b-f) display high contrast between the lesions and surrounding white matter, suggesting that this echo train may provide clinically useful contrast characteristics that appear very similar to those for conventional T2-weighed SE images (Fig. 2a). However, as evidenced by the exceptionally long effective TE of 328 ms, the associated contrast behavior differs from that of established echo-train techniques and requires further investigation. The thin 1-mm sections provide an improved definition of lesion location and extent; the lesions seen in the 2D image appear, to varying degrees, in three adjacent 1-mm sections. Furthermore, the overall image quality for the very long SE-train and conventional-SE images is similar, despite the much thinner sections of the former. Figures 2e and f, depicting the largest lesion in sagittal and coronal orientations, respectively, demonstrate the capability for high-quality images in arbitrary orientations.

FIG 1: Variable flip-angle series for the 160-echo 3D images shown in Fig. 2.



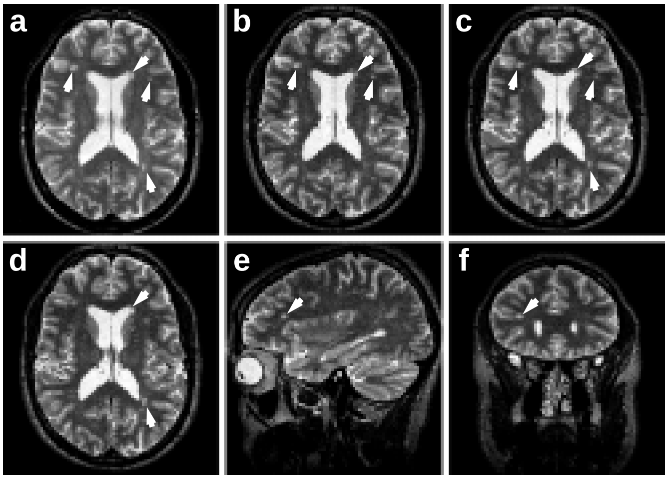


FIG 2: T2-weighted (**a**) 2D and (**b**-**f**) 3D SE images from a volunteer with non-specific white-matter lesions (arrows). The three 1-mm thick 3D images in (b)-(d) correspond to the single 3-mm thick 2D image in (a). In the 3D images, the phase-encoding direction corresponding to the 160-echo train is left-to-right in (b)-(d) and (f); no image artifacts secondary to this very long SE-train are apparent. For the 10 min. 3D acquisition, parameters were TR/effective TE, 2750/328 ms; matrix, 256 x 160 x 216; FOV, 25.6 x 16.0 x 21.6 cm; echo spacing, 4.1 ms; ETL, 160. For the 14.8 min. 2D acquisition, parameters were TR/TE1/TE2, 2750/20/80 ms; matrix, 256 x 160; FOV, 25.6 x 16.0 cm; thickness, 3.0 mm; sections, 54.

CONCLUSIONS

Very long SE trains with prescribed signal evolutions permit brain imaging with both adequate S/N and useful contrast properties, and thus provide a vehicle for substantially reducing the imaging time. For example, a half-Fourier acquisition (as described in [3]) combined with the very long SE-train T2-weighted method (Fig. 2) could provide 1-mm isotropic resolution of the whole brain in about 5 minutes, and a 3D single-slab FLAIR version [4] could provide 3-mm contiguous sections of the whole-brain in less than 5 minutes.

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