Sub-Minute High Angular SENSE DTI at 3.0 Tesla for Fiber Tracking

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INTRODUCTION

The first possibilities for white matter tracking were introduced late last century [1, 2]. The sequences that were used for this fiber tracking analysis were based on multi-shot SE-EPI acquisitions [2,3] and required quite long scan times up to 60 minutes. Moreover, these techniques only acquired the minimum of six diffusion directions, which are needed to calculate the diffusion tensor.

Various authors introduced better diffusion schemes to obtain a higher rotational accuracy of the diffusion tensor [4]. These so-called high-angular resolution diffusion imaging experiments acquired up to 126 diffusion directions and dramatically extended the total scantime per slice [4]. However, it is shown by Jones that around 15 diffusion directions are sufficient to create a robust - rotational insensitive - estimate of the diffusion tensor [5].

Other new techniques created possibilities to improve on the diffusion weighted images themselves. SENSE was introduced by Pruessmann et al. [6], which allowed to reduce the length of the EPI readout and thus minimize the width of the point-spread-function (PSF). The first proof of this high image quality in single-shot SE-EPI imaging was shown by Bammer et al. using a six-element coil [7]. Since then many authors have shown the clinical possibilities of fibertracking exactly according to the above methods [8,9]. Last but not least, the introduction of ultra-high field MR systems by various vendors have created further possibilities to improve on the SNR of diffusion tensor imaging.

In this study we combine the above mentioned techniques on a state-of-the-art 3.0 Tesla system with a ultra-high performance gradient system to acquire full-brain, high spatial resolution, high-angular resolution in less then one minute. It is shown that one can acquire fast high image quality that is perfectly suitable for fibertracking analysis.

METHODS

All experiments were performed on a 3.0 T Intera system (Philips Medical Systems, Best, The Netherlands) using a SENSE headcoil and a Quasar Dual force-balanced gradient coil with maximum amplitude of 80 mT/m and slew of 200 T/m/s.

Four subjects were scanned. After a survey and reference scan (with a total of 45 seconds) a high-resolution 3D-T1 was performed to use as an underlay in the determination of the various white matter tracts.

A high-angular resolution diffusion imaging experiment was performed using 15 diffusion directions and 27 slices of 3.5 mm. A standard SE-EPI Stejskal-Tanner sequence was applied, using a diffusion gradient strength of 77.5 mT/m and duration of 10.7 ms with 19.8 ms between the onsets of the two bipolar gradients. A b-value of 800 s/mm^2 was obtained in this manner. A FOV of 220 mm was used, with a matrix of 96 (interpolation to 128) resulting in a scanned spatial resolution of 2.3*2.3*3.5 mm^3. Furthermore, a half-fourier acquisition of 60% was used and a SENSE factor of 3 was applied in the Anterior-Posterior direction resulting in a TE of 41 ms and TR of 3.6 s. The total acquisition time was 58 seconds (16 TR's). The data was further analyzed using prototype fibertracking software on the PRIDE workstation (Philips Medical Systems, Best, The Netherlands), to obtain some of the well know tracts in the brain stem.

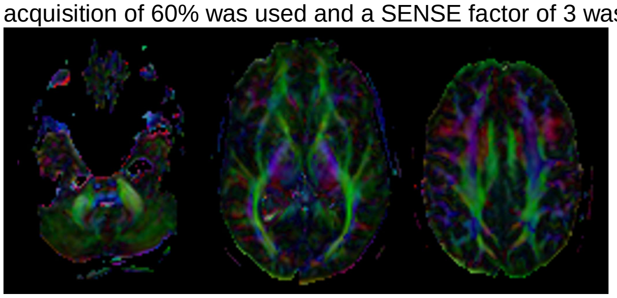

Figure 1: Colored FA maps are shown for three slices from a 58 seconds high-angular DTI acquisition with a b-value of 800 s/mm^2. Blue indicates feet-head diffusion, green anterior-posterior and red identifies right-left diffusion.

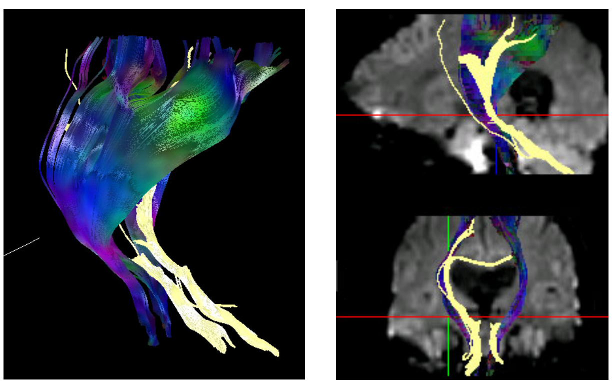

Figure 2: Two fiber tracts are shown from the dataset shown in figure 1. The corticospinal tact (blue-green) and superior cerebellar peduncle (yellow) are shown in 3D (left) and projected (right).

RESULTS

High SNR images were obtained as a result of the high field strength and short echo-times. No ghosting or other artifacts were seen in any of the images of all subjects. The colored FA maps show a clear delineation of many white matter fibers in the complete brain (Fig. 1). A number of tracts were obtained using the *two-roi* method of Mori et al. [10]. In figure 2 an example is shown of the corticospinal tract (blue/green) and the superior cerebellar peduncle (yellow).

DISCUSSION

In this study it is shown that high-angular DTI for fibertracking can be performed in sub-minute acquisitions, which will allow high-angular DTI and fiber tracking to become a fast clinical procedure. The high SNR is a result of both the high field system but also results from the short-TE that is only possible utilizing this ultra-strong gradient system.

Further modifications may even speed up this acquisition. For example, when optimal diffusion schemes are chosen we can reduce the number of diffusion directions. But also, we may reduce the b-value and a total acquisition time of 30 seconds may be possible.

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