Reduction of Diffusion Tensor Imaging Acquisition Time with Wideband MR Imaging

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Abstract

A Wideband diffusion tensor imaging is successfully performed to acquire two images in one single excitation. 2-slices are excited/acquired simultaneously using 2D Wideband modified pulse-gradient spin-echo sequence. The calculated diffusion tensors of the grapefruit are clearly displayed on the eigenvector map, and proven to be correct. The result of this study directly indicates a reduction of more than half the time for diffusion tensor imaging of large coverage such as whole brain DTI.

Introduction

Diffusion tensor imaging (DTI) [1] provides *in vivo* microscopic information of intravoxel fiber orientation by probing the diffusion of water molecules. Higher angular resolution diffusion imaging (HARDI) [2] and diffusion spectrum imaging (DSI) [3] are further proposed to resolve intravoxel multiple fiber structures. However, diffusion MRI on brain researches needs long scan time due to long repetition time (TR) caused by large number of slices to cover the whole brain. For some experiment settings, repetition time becomes too long that magnetization has already fully recovered in the early excited slices, making the TR length inefficient. In the field of accelerating MR diffusion imaging, Feinberg et al. presented that the Simultaneous echo refocusing (SER) technique that could encode multiple two-dimensional Fourier transform images within a single echo train [4], reducing the scan time of whole brain DSI [5]. But this sequence extended from EPI inherits its disadvantages such as image quality, artifacts and other issues, not to mention the RF pulse requirements. Aware of these limitations, we propose another method called "Wideband MRI" to accelerate diffusion imaging. In wideband MRI, acceleration is accomplished by extension of the MR signal bandwidth during excitation as well as acquisition. Wideband multi slice/slab factor (W) is defined as the factor of bandwidth extension. This method has already been successfully applied in 2D gradient echo and easily doubled the acquisition speed using W=2.

Materials & Methods:

The images were acquired by a 3 Tesla MRI system (Bruker, Germany) with a maximum gradient strength of 3 Gauss/cm. DTI were acquired with 12 gradient encoding directions and 1 reference image using a pulse-gradient spin-echo sequence with TR/TE = 3000/130 ms, FOV =11x11 cm^2, matrix size=128x128, and slice thickness = 2 mm, Δ/δ= 100/18 ms, b=773 s/mm2. Two grapefruits are lined along the axial direction, 2-slice excitation using cosine-modulated sinc pulses that are 125 kHz, which is 13cm apart in space. RF excitation power is fine tuned for optimal SNR.

Results:

Fig. 1 illustrates the excited slices of one modulated pulse, also indicating the spatial relation of the two grapefruits., as well as the image acquired by a 2-slice Wideband spin echo sequence with no diffusion gradient applied, serving as a localizer image. The image of the grapefruit A has a better SNR for it is closer to the center of the RF coil while B is almost at the end. The 1st eigenvector map of a grapefruit was shown in Fig. 2. The radial structure of grapefruit can be accurately resolved using 2-slice Wideband DTI.

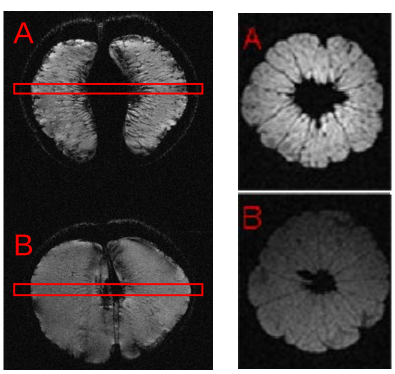

Fig.1 Sagittal localizing image (left) and image using Wideband spin echo sequence with W=2 (right). Grapefruit A is positioned near the center of the RF coil thus better image quality. The 2 slices were excited/acquired simultaneously.

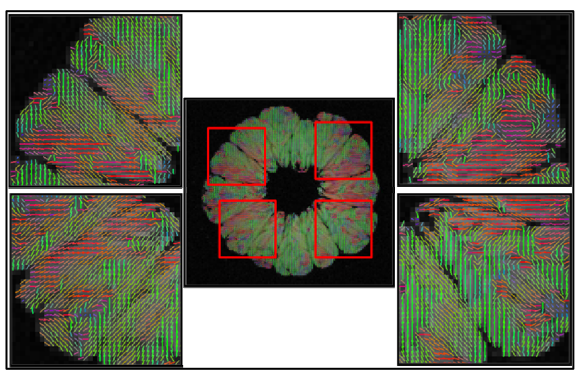

Fig. 2. First eigenvector map of one of the slices of a grapefruit A 12gradient encoded DTI is acquired with Wideband DTI with W=2 Diffusion tensor show radiating patterns of grapefruit pulps, a true reflection to its anatomical structure.

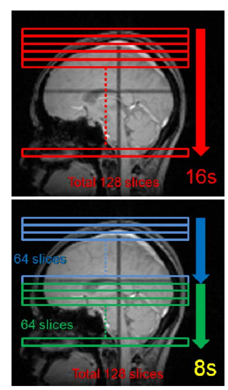

Fig.3. Illustration of how Wideband DTI reduces scan time. TR is to acquire total N slices but when 2 slices are acquired Simultaneously with W=2, only TR/2 is needed.

Conclusion:

The success of this experiment demonstrates the ability to accelerate whole volume diffusion imaging time by shortening the TR. With Wideband multi-slice acquisition combined with DTI, less number of acquisitions is required. The time reduction mechanism is depicted in Fig. 3. For human brain DTI experiment that acquires 128 slices, TR would have to be forced to exceed 16sec to contain all slices. Applying Wideband DTI with W=2, only 64 excitations/acquisitions are needed for whole coverage. The calculation is straightforward, TR can be reduced to 8sec and total scan time can be cut to half. More experiments such as faster animal whole brain DTI/ HARDI will be tested to fully demonstrate the potential of this technique.

References:

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