3D Diffusion Tenosr Imaging with 2D Navigated and Online Motion Corrected RARE

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Introduction

DTI is a powerful method for mapping microstructure and has a range of potential applications in medical diagnosis and structural exploration of the human brain. The diffusion preparation makes the NMR signal sensitive to microscopic thermal motion, but also macroscopic motion such as bulk motion of the subject or brain pulsation results in unwanted phase errors (1,2). Hence, 2D single shot imaging sequences like echo planar imaging (EPI) are commonly used which are insensitive to these phase errors but are also limited in spatial resolution. To overcome the latter, segmentation of the image data is necessary and the phase errors either have to be eliminated by discarding the erroneous signal part or have to be corrected as it is done by navigator techniques. Some of the latter have already been introduced for 2D DW methods (3,4,5). This work proposes a 2D Cartesian navigator with online motion correction without sensitivity loss (6) combined with a 3D RARE sequence. Isotropic high resolution DTI maps are thus achieved

Materials and methods

Experiments were performed on a 3T BRUKER MedSpec whole body system. The sequence depicted in figure 1 was ECG triggered 400 ms after the R-wave to avoid brain pulsation during the diffusion preparation. In order to reduce the effect of eddy currents a twice refocused diffusion weighting scheme was optimised (7). To obtain the information of the diffusion tensor, a scheme with seven directions for diffusion weighting was used. The 2D blipped EPI navigator was applied orthogonal to the diffusion weighted direction to register all phase errors due to subject rotation and translation (1). The navigator data was acquired with an external data logger which also performed the calculation for the correction pulses. These were applied between the navigator and the beginning of the RARE readout. Additionally, an extra refocusing pulse was inserted between the navigator and the correction pulses to acquire the navigator data during the spin-echo after the last preparation pulse to avoid modulation of navigator signal due to T_2^* relaxation. The evaluation of the navigator data was performed in k-space calculating the coordinate and the phase of the signal maximum. A reference with no diffusion weighting for the k-space coordinate and phase had to be acquired which was subtracted from the corresponding values in case of diffusion weighting. All calculations were performed for each direction of diffusion weighting. Further correction of the eddy currents of the navigator readout was necessary. Therefore navigator templates with different dephasing gradients in navigator read direction were acquired. They sampled the 2D distribution of the eddy current effect which depends on readout coordinate and readout index. This eddy current effect of the navigator had to be taken into account when the correction pulses are calculated from the navigator signal. In order to reduce scanning time and image artefacts only the sinc pulse for excitation was slice selective. All the succeeding refocusing pulses were non-selective, hence constant rf-pulses could be used discarding the slab profile. Additionally, variable flip angles (7) were applied reducing the SAR and achieving longer RARE echo trains. The image data were acquired with a matrix of 134 x 99 x 15 and a field of view (FOV) of 201 mm x 148.5 mm x 22.5 mm resulting in an isotropic resolution of (1.5 mm)^3. Diffusion weighting was performed at b=50 (one repetition) s/mm^2 and b=700 (two repetitions) s/mm^2.

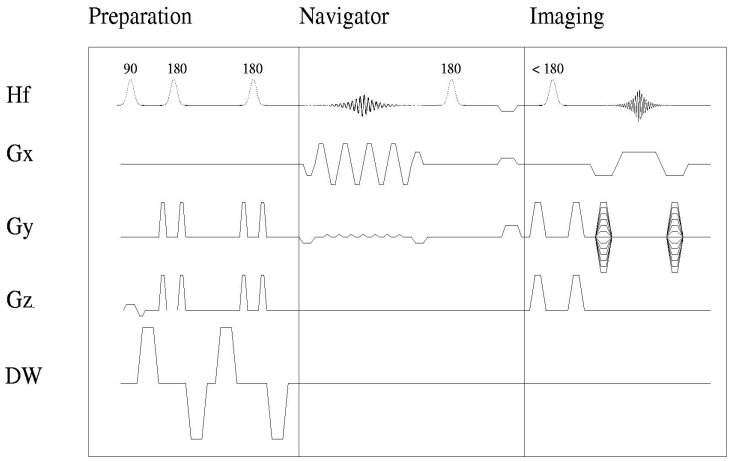

Fig 1 sequence scheme

Results and Discussion

In figure 2, there are seven coronary diffusion weighted slabs presented with different diffusion weighted directions which show different contrast due to the anisotropic structure of the corpus callosum. In figure 3, there is an axial section showing typical diffusion contrast. In figure 4, the presentation of the eigenvectors corresponding to the maximal eigenvalue of the diffusion tensor reflects realistic fibre trajectories. The remaining artefacts may stem from a variety of causes. Subject movements during the long measurement time (~ 1 hour) has to be mentioned, which lead to partial volume effects. Another point is the demanding imaging method which combines a multi pulse sequence with diffusion weighting resulting in image artefacts due to the effect of eddy currents on pulses and navigator. However, undistorted 3D DTI based on RARE seems to be a promising approach to high resolution tractography.

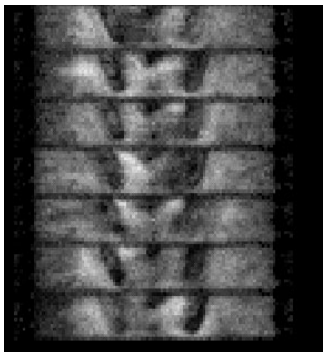

Fig 2 Coronary section for 7 dw. Directions

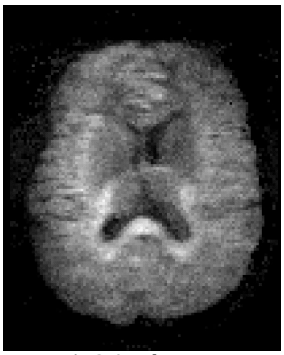

Fig 3 Axial section

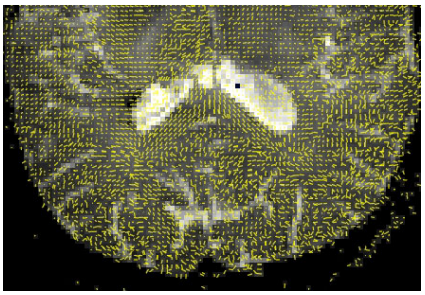

Fig 4 Axial section of the eigenvectors to the corresponding max. eigenvalue of the diffusion tensor

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