Diffusion Spectrum Imaging with PROPELLER EPI Acquisition

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Introduction

Diffusion Spectrum Imaging (DSI) is an imaging technique capable of resolving intra-voxel fiber crossings and has been widely utilized to study neuronal fiber tracts in human brain [1]. Since DSI technique requires hundreds of diffusion directions being sampled in Cartesian coordinate of q-space and takes very long acquisition time, echo-planar imaging (EPI) was usually employed to acquire the DSI data due to its high time-efficiency and high signal-to-noise ratio. However, the insufficient bandwidth in the phase-encoding direction caused strong susceptibility distortions in diffusion-weighted EPI. PROPELLER EPI was demonstrated to have capability of reducing susceptibility distortions and has been utilized to acquire DTI data [2]. Also, by using the keyhole reconstruction, the PROPELLER EPI can be further harnessed to reduce susceptibility distortions in QBI without lengthening acquisition time [3]. Hence, the purpose of this study was to employ PROPELLER acquisition to acquire DSI data and compare the fiber tracts with those of conventional DSI.

Materials and methods

In this study, DSI data were collected from a 21 y/o healthy male subject in a 3T MR scanner (GE Signa VH/I, GE Healthcare), equipped with 16-channel phase array neurovascular coil, by using twice-refocused spin-echo diffusion-weighted pulse sequence with the following parameters: TR/TE = 4300/144.9 ms, b-value = 3500 s/mm2, # of diffusion direction = 208, matrix size = 96x96, ASSET acceleration factor = 2 and half Fourier = 0.6, resulting in an EPI factor = 24, FOV = 240x240 mm, slice thickness = 5mm, number of slice = 25, scan time = 15m03s. For PROPELLER DSI, the 208 DWIs were separated into 13 PROPELLER sets each of which consisted of one b0 and 16-direction DWIs acquired with same slice orientation as prescribed in conventional DSI. Other imaging parameters were: TR/TE = 4200/135.7 ms, b-value = 3500 s/mm2, blade size = 34 x 96 (64.5% reduction in frequency-encoding direction), rotating angle per blade = 25 degree, ASSET acceleration factor = 2, and half Fourier = 0.6, resulting in an EPI factor = 31, FOV = 240x240 mm, slice thickness = 5mm, number of slice = 25, and total scan time = 16m28s. To compare the susceptibility distortions between conventional DSI and PROPELLER DSI, the distortion-free turbo-spin-echo T2WIs were also acquired with the same slice orientations and thickness as prescribed in DSI acquisitions. The imaging parameters for TSE T2WI were: TR/TE = 3383/102 ms, echo-train-length = 16, matrix size =192x192, FOV = 240x240mm, slice thickness = 5mm, number of slice = 25.

In PROPELLER DSI, the PROPELLER DWIs were reconstructed by PROPELLER keyhole technique which shares outer k-space of all blade DWIs with each other, but retain central k-space to preserve their own diffusion contrast. Besides, affine and demon registrations were utilized to minimize blurring effects in PROPELLER EPI [4]. Afterwards, all DSI data were processed off-line by using DSIstudio (Advanced MRI Lab, NTUH) software, and the callosal fibers and cortico-spinal tracts were traced with streamline-based tracking algorithm (turning angle < 50 degree, # of tracts = 5000, step size = 0.2 voxel). For callosal fibers, the seeding points were placed in the mid-sagittal plane to encompass the entire corpus callosum. For cortico-spinal tracts, the seeding points were placed in the bilateral cerebral peduncles.

Results

Figure 2 shows the sagittal views of TSE T2WI, single-shot EPI and PROPELLER EPI. It is obvious that, due to insufficient bandwidth in phase-encoding direction, the susceptibility distortions were very prominent in single-shot EPI especially in brain stem areas, as pointed by the yellow arrow. With PROPELLER acquisition, the distortions were substantially reduced. Figure 3 shows the callosal fibers and cortico-spinal tracts of conventional DSI and PROPELLER DSI. In conventional DSI, it was noted that the cortico-spinal tracts were mostly terminated in the brain stem due to susceptibility distortions, as pointed by the white arrow, while in PROPELLER DSI cortico-spinal tracts can reach to lower region of brain stem.

Figure 1

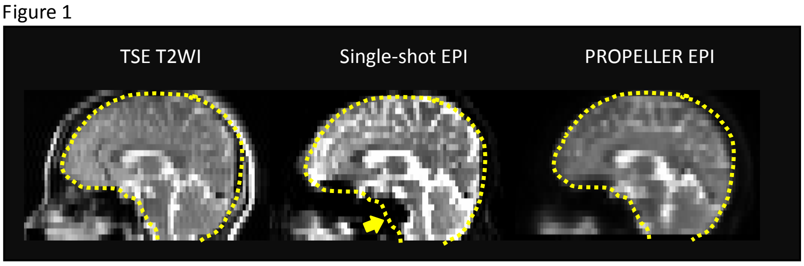
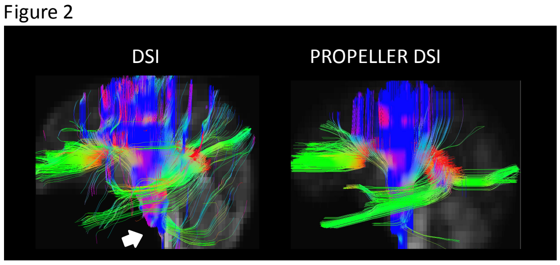


Figure 2



Discussion

This study performed PROPELLER EPI in conjunction with PROPELLER keyhole reconstruction to reduce susceptibility distortions in DSI without prominent increase of scan time. The results showed that the fiber tracts were in better agreement with anatomical locations in TSE T2WI, especially in bran stem area, suggesting that the PROPELLER DSI has potential of improving tracking results. However, further investigations are needed to quantitatively compare the tract differences between two acquisitions.

References

[1] Wedeen VJ, et. al., MRM, 2005. [2] Skare S, et. al., MRM, 2006. [3] Chou M, et. al., ISMRM, 2006. [4] Chou M, et. al., ISMRM, 2010.