Q-ball imaging with PROPELLER acceleration

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Purpose

Q-ball imaging [1] has been proven to have ability of resolving intra-voxel fiber crossings. Compared to DSI (Diffusion Spectrum Imaging) [2] it only requires one-half diffusion-weighted images (515-dirs vs 252-dirs), and takes only about 30 minutes to acquire whole brain data. However 30 minutes acquisition time still hinders its clinical applications. Therefore, we propose PROPELLER QBI technique using PROPELLER EPI acquisition [3] for acceleration, such that the total scan time can be shorter than 20 minutes .

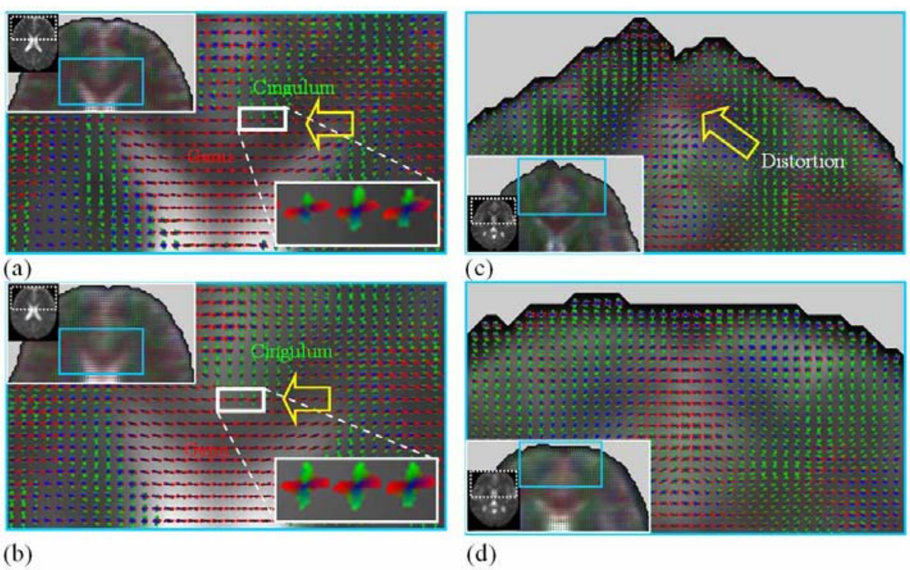
Materials and Methods

PROPELLER EPI acquisition was demonstrated suitable for high field strength for its ability of reducing susceptibility distortion. This technique constructs a high-resolution EPI by combining several rotating low-resolution EPIs (called BLADE images), which combines every blade's low- and high-frequency parts to fill out entire circular k-space. In this study, we retain the k-space center with diffusion weighting at different diffusion directions, and share each blades' high-frequency part to form high-resolution PROPELLER images (e.g., 14 low-resolution rotating blades to reconstruct 14 high-resolution images). The method is termed PROPELLER keyhole reconstruction. Our implementation first separated 252 diffusion-weighted images into 14 groups (14 blades) according to their diffusion directions. Each group comprised 18 different diffusion-weighted blade images having the same rotation angle (18x14=252). After obtaining 252 diffusion-weighted blade images, we performed PROPELLER keyhole reconstruction to form 252 high-resolution diffusion-weighted images, which are subsequently used to perform QBI reconstruction.

Two imaging data sets were acquired for each of our three healthy subjects: one has 252 full k-space DWIs (QBI) and the other has 252 PROPELLER-based DWIs (PROPELLER QBI) with each blade covering only 30% k-space. Data were acquired from a 3T MR system (Philips Achieva, Best, the Netherlands). In QBI, the parameters were set as following: matrix size = 112x112, TR = 6134 ms, ETL = 22 after SENSE, and total scan time of 26 minutes. In PROPELLER QBI, the parameters were: matrix size = 34x112 (70% phase reduction), # of blade = 14, angle per rotation = 25, TR = 3976 ms, ETL = 7 after SENSE, and total scan time of 18 minutes. Both used a TE of 100ms, 3mm slice thickness, 30 slices, b-value of 4000 s/mm^2, and SENSE factor of 3 with 0.6 partial Fourier acquisition.

Results

Figure 1 compares the ODF (Orientation Distribution Function) maps of QBI and PROPELLER QBI. We see that the ODF maps from these two acquisitions exhibit good similarity in fiber orientations. In Figs.1a and 1b, yellow open arrows point out the fiber-crossing of cingulum and genu fibers from corpus callosum, well resolved by both QBI and PROPELLER QBI. In QBI, region near frontal sinus shows susceptibility distortions (Fig.1c), which is reduced by using PROPELLER QBI (Fig.1d) acquisition.



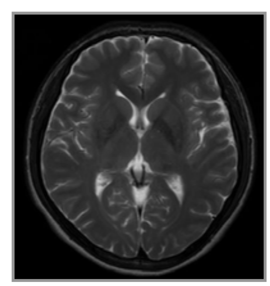


Figure 1 shows the ODF maps derived from QBI (a & c) and PROPELLER QBI (b & d) with T2WI acquired using fast spin-echo (e) at same level as c & d. In a and b, we enlarge the genu region of corpus callosum, showing the crossing of cingulum and genu fibers. In c and d, we enlarge the region near frontal sinus. Yellow open arrow in (c) points out the distorted area, and is reduced by using PROPELLER QBI (d) as compare to the FSE image (e).

Discussion and conclusion

Whole brain PROPELLER QBI acquisition helps reducing scan time to 18 minutes without prominent loss in information on fiber crossings. The ability of PROPELLER imaging to reduce susceptibility distortions could also be retained. Therefore, we conclude that PROPELLER QBI is a suitable technique for clinical applications for its unique ability of reducing scan time and susceptibility distortions.

References

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