Improving the Efficiency of Tractography by Combining DTI with Prospective Partial-brain Q-Ball Imaging

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Introduction Diffusion tensor imaging (DTI) has become a popular tool to provide the information about structural connectivity within biological tissues. However, DTI technology has a significant limitation in resolving intravoxel orientational heterogeneity due to the constraints of the tensor model. Such limitations have prompted the development of diffusion imaging methods capable of resolving intravoxel fiber crossings, such as Diffusion Spectrum Imaging (DSI) and Q-Ball Imaging (QBI) [1]. But most of these methods require a much large number of diffusion gradient directions and therefore need a long acquisition time, which is undesirable for most clinical and neuroscience applications. Furthermore, the percentage of appearance of major fiber crossing in voxels is about 5%-15% within human brain [2]. In other words, the conventional DTI, which can be achieved by a relatively small number of diffusion gradients (normally 20-50 directions), may still be valid in about 85% voxels. Here we present a new imaging scheme which combines the conventional DTI and partial brain covering QBI to improve the efficiency of fiber connectivity detection.

Materials and Methods A whole brain DTI data set was collected with 48 diffusion directions, followed by a QBI acquisition with 128 diffusion directions. QBI was employed only over the regions of interest and the regions where we expected to find more crossing fibers as shown in Figure 1A. The areas with possible fiber crossing were identified by detecting the non-Gaussian apparent diffusion coefficients (ADC) in DTI data [2]. For comparison, a whole brain QBI scan was also performed in this experiment. All diffusion images were acquired on two human subjects using a spin-echo EPI pulse sequence on a Siemens 3T Trio scanner. The 2.5mm×2.5mm×2.5mm resolution axial slices were scanned with 51 slices for whole brain coverage and 19 slices for partial brain coverage. Diffusion weighting of b = 1000 s/mm^2 was used for DTI scans and b = 6000 s/mm^2 for QBI scans. In the post-processing, the DTI and QBI data were co-registered based on a set of high-resolution 3D anatomical images using Brainvoyager software. DTI and QBI were integrated using multiple wavevector fusion (MWF) algorithm [1] to produce orientation distribution function (ODF) with our Matlab program. Within the coverage of QBI, multiple fiber assignment by continuous tracking (MFACT) algorithm was applied for constructing 3D fiber connections [3], in which multiple maxima of the ODF at a voxel were used in tractography.

Results and Discussion The results are similar between two subjects. The major areas with possible fiber crossing detected by the Alexander's non-Gaussian ADC method [2] are presented in Figure 1A. These regions are also validated by the ODF results from whole-brain QBI. If more than one peak of calculated ODF is above a certain threshold and the divergence angle between them is larger than 20°, the associated voxel is regarded as the location with fiber crossing. The resulting area is similar to that detected by the Alexander's algorithm, covering about 14.6% of the voxels within human brain. In that area, DTI-derived principal eigenvectors do not coincide with the maxima of ODF, i.e. fiber directions, as depicted in Figure 1B. The regular fiber tracking of DTI can not pass through these fiber-crossing voxels without errors, and the tracking may be incomplete at the end. Thus, the resulting fiber length from DTI will be shorter than that from the current DTI/QBI combination approach (see Table 1). The directional correlation (DC) index along the white matter tract will also be lower in the DTI [4]. As shown in Table 1, the whole brain QBI has the limited improvement in the fiber tracking results comparing with the DTI/QBI combination approach, while the scan time is 9 minutes (i.e. 65%) longer. Thus, our DTI/QBI combination is more time-efficient than conventional whole brain QBI without much sacrifice in the quality of fiber tracking results (displayed in Figure 1C). The acquisition time can be reduced further if the hemisphere QBI with MWF is used [1]. Another advantage of this combination is the provided flexibility and more options that a short time *ad-hoc* QBI can be performed at a different time, if a serious fiber crossing problem is found in the existing DTI data and in the brain areas of interest. In conclusion, DTI combined with partial brain coverage of QBI can improve the efficiency of neural connectivity detection.

Reference [1] Khachaturian, et al. *MRM* 2007: 57, 289. [2] Alexander, et al. *MRM* 2002: 48, 331. [3] Chao, et al. *ISMRM* 2007: 1550. [4] Sun, et al. *MRM* 2003: 49, 271.

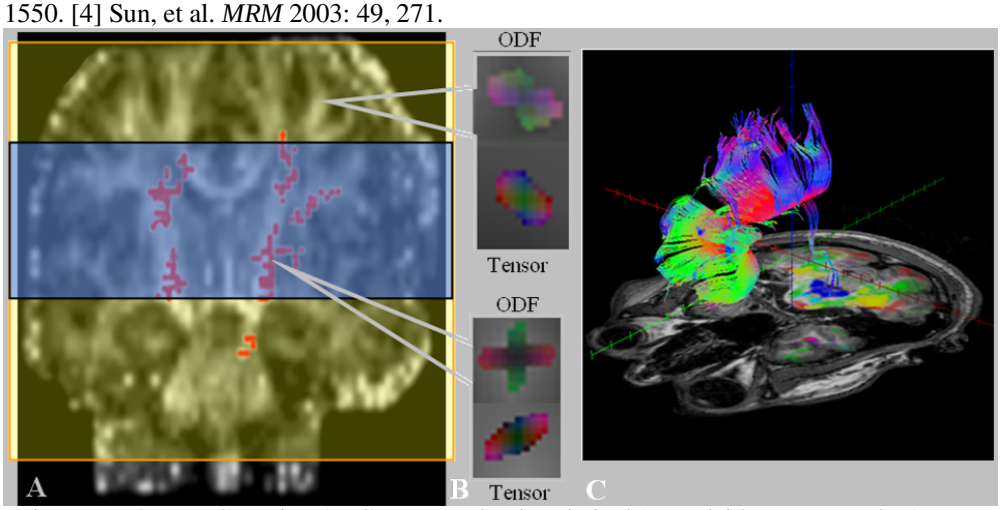

Figure 1. **A**: non-Gaussian ADC areas (red colored pixels) overlaid on a coronal FA map. Yellow shade represents DTI coverage and blue shade represents QBI coverage. **B**: tensor ellipsoid from DTI and ODF map from QBI at two different voxels. **C**: fiber tracking result from combined DTI/QBI.

	DTI vs DTI/QBI	QBI vs DTI/QBI
DC index difference	-22.5%	6.5%
Fiber length difference	-16.6%	7.3%
Scan time	-61.5%	65.3%

Table 1. Comparison results between different methods.