Improved Diffusion MR Fiber Tracking for Neurosurgical Applications

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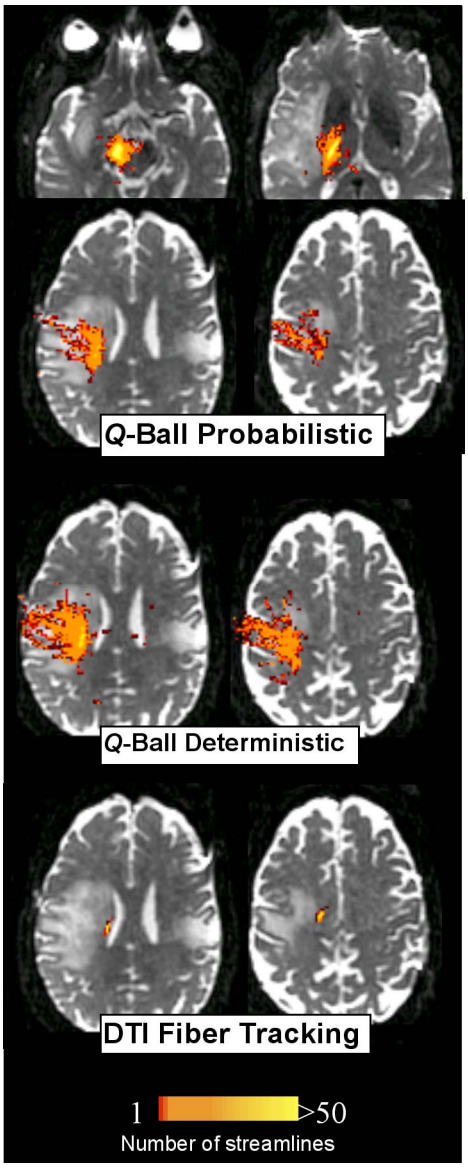
Introduction: Diffusion MR fiber tracking is a non-invasive technique that can accurately delineate specific white matter tracts in 3D. DTI fiber tracking has become a routinely used tool for deciding if a brain tumor can be safely resected, planning a surgical approach, and then avoiding damage to eloquent tracts such as the motor pathway. However, there are known limitations of the diffusion tensor model and DTI fiber tracking fails in regions with crossing white matter fibers. The q-ball reconstruction of high angular resolution diffusion imaging (HARDI) data can distinguish crossing fiber populations. Fiber tracking based upon the *q*-ball orientation density function has been shown to be able to traverse white matter regions with complex architecture and reveal a greater portion of the motor tract [1]. In this study, a residual bootstrap probabilistic *q*-ball fiber tracking technique was used to delineate the motor tract in brain tumor patients. The HARDI acquisition and *q*-ball fiber tracking were both performed in a clinically feasible time as part of a routine presurgical MR scan protocol. Results of probabilistic and deterministic *q*-ball fiber tracking are compared to the currently used DTI fiber tracking technique.

Methods

Imaging: Whole brain HARDI data was acquired from 4 adult patients with cerebral gliomas. Imaging was performed on a 3 T GE Signal EXCITE scanner, with ASSET factor 2, TR/TE=12.4s/73ms, 2.2x2.2x2.2 isotropic voxels, FOV =280x280mm, and 128x128 matrix zero filled to 256x256 matrix. 55 diffusion gradient directions were acquired with b=2000 s/mm^2. Total imaging time was approximately 13 minutes.

Probabilistic Q-Ball Fiber Tracking: The residual bootstrap was used to estimate the uncertainty in the orientation density function (ODF) [1]. The diffusion-weighted data was fitted to fourth order spherical harmonic basis functions [2]. Residuals are the difference between the measured data and synthetic data generated by inversion of the spherical harmonic model fit to the measurements [1]. The fiber tracking algorithm follows the peaks of the generated ODFs from voxel to voxel. When a streamline enters a new voxel, a unique ODF is constructed with the bootstrap resampled data and the peaks of the ODF identified. The ODF peak with orientation closest to the incoming streamline orientation is chosen for propagation. In this Monte Carlo type approach, the streamlines entering a voxel are dispersed according to the distribution of ODF peaks in each voxel [1]. To delineate the motor tract in the brain tumor patients, fiber tracks were launched from a region drawn in the cerebral peduncle and seeded with 64 starting points equally spaced within each voxel. Streamlines passing through target regions drawn in the posterior limb of the internal capsule were retained. For comparison, *q*-ball fiber tracking was performed without bootstrap resampling and DTI fiber tracking was performed based upon the FACT streamline method [3].



Results As seen in the figure example, both *q*-ball fiber tracking methods were able to delineate the motor tract from the midbrain to both the superior-medial and lateral portions of the motor cortex in our subjects. The *q*-ball streamlines pass along the borders of the tumor and through regions of edema. DTI fiber tracking revealed connectivity from the midbrain to only the medial-superior aspect of the motor cortex.

Discussion/Conclusion

During radical resection of a brain tumor, knowledge of the location of the motor tract is critical for avoiding postsurgical functional deficit. *Q*-ball fiber tracking methods demonstrated the ability to more fully delineate the lateral sections of the motor tract, providing an additional margin of safety around the white matter controlling head and face movements. The HARDI acquisition used for this study was acquired in a clinically feasible timeframe and *q*-ball fiber tracking has the potential to be routinely used for surgical planning.

References

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