Clinically feasible crossing fiber tractography based on additional local HARDI

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Introduction For analysis of complex fiber structures in the presence of multiple fiber orientations like crossing, HARDI (High Angular Resolution Diffusion Imaging) acquisition technique is essential. A major problem of HARDI in clinical situation is its long scan time. If a whole brain is scanned using HARDI (e.g., 60 MPG directions), a typical scanning time is about 20 min for 50-70 slices. However, when tract of interest is limited (e.g. the pyramidal tract for neurosurgical planning and navigation), HARDI may be performed only for fewer slices in fiber crossing areas, and consequently scan time may be reduced. In this study, we propose a local hybrid diffusion imaging (local-HYDI) composed of whole brain imaging using LARDI (Low Angular Resolution Diffusion Imaging) and local brain imaging using HARDI for crossing fiber areas. Using the local-HYDI data, we also present a Hybrid Tractography (HT) technique based on adaptive selection of deterministic and probabilistic techniques according to data type (LARDI or HARDI) of the location. In comparison with Hybrid Diffusion Imaging [1] and practical crossing fiber tracking with combined DTI datasets [2], an important feature of our technique is local HARDI adapted for the coverage of crossing fibers. In this abstract, we describe the method and the feasibility evaluation results.

Materials and Methods

(a) ***Imaging*****:** A 3.0 T GE Signa HDx MR clinical system was used. Local-HYDI composed of both whole brain with LARDI (12 MPG directions, b-value 1000 s mm^{-1}, 2x2x2.5 mm, 60 slices, TR 17 s) and local brain with HARDI (60 MPG directions, 16 slices, TR 5 s) were obtained from seven healthy volunteers. Local HARDI was acquired near the superior border of lateral cerebral ventricle. For comparison, we scanned whole brain with HARDI (30 and 60 directions). The 30-dir-scan is one of a clinical standards in our hospital. The 60-dir-scan data set was used as the gold standard. The target is the pyramidal tract including the cortico-spinal tract (CST) and the cortico-bulbar tract (CBT), which intersects mainly with the superior longitudinal fasciculus (SLF).

(b) ***Tractography*****:** The HT is performed with deterministic tractography (DT) using single tensor model in LARDI data and probabilistic tractography (PT) using partial volume model [3] to handle fiber crossing in HARDI data using FSL. We set BEDPOSTX (FSL toolbox) with a maximum of three fiber populations at each voxel, and we built our modified version of the ProbTrack (FSL toolbox) to implement the proposed HT method so that the PT and the DT can be switched depending on data types (LARDI or HARDI). Fig.1 shows the imaging coverage of Local-HYDI and the method of HT.

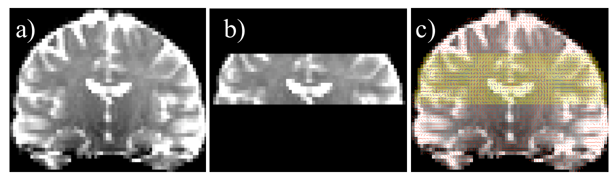

Fig.1 Local-HYDI and Hybrid Tractography:
(a) whole brain with LARDI and (b) local brain with HARDI in b0 image, (c) The yellow area indicates PT method and the other areas are DT method.

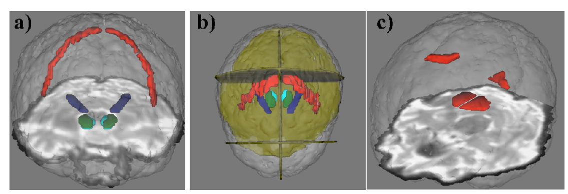

Fig.2 ROI placement for tractography: (a) seed masks (red), target masks (blue, green), and termination masks (cyan), (b) exclusion masks (yellow), (c) example of additional exclusion masks depending on subject.

Results

Fig.2 shows ROI masks. The tractography algorithm generated 25,000 samples from each voxel in motor areas. A curvature threshold of 80 degrees and a volume fraction threshold of 0.10 were used for termination of tracking. Displayed fiber volume was limited to only voxels where 5 or 10 samples had passed through. Fig.3 shows the 3D reconstruction of the pyramidal tract with the methods; DT-12, PT-30, HT-12/60, and PT-60. The DT-12 failed to trace the lateral CBT while the other techniques depicted them. Fig.4 shows DICE coefficient (DC) and ratios for false positives (FP) and false negatives (FN). Each scan time was as follows; DT-12 (255 s) < PT-30 (561 s) ≈ HT-12/60 (570 s) < PT-60 (1071 s).

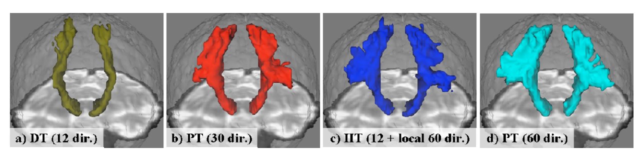

Fig.3 The 3D reconstruction of fibers (thresholded of 5).

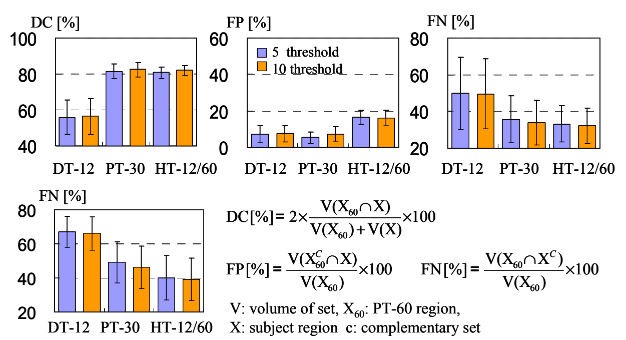

Fig.4. DICE coefficient (DC), FP ratio, and FN ratio for 7 volunteers. The upper figures are for whole brain area and the lower one is for local brain area (yellow area in Fig.1 (c)).

Discussion and Conclusions

The total scan time of proposed local-HYDI protocol was about 9.5 min. It showed that local-HYDI is a clinically feasible scan time while HT can depict crossing fibers in CBT. While the DC of HT-12/60 was about 82% similar to the result of PT-30, HT-12/60 yielded more FP than PT-30. We confirmed that the main reason for FP was based on a crosstalk artifact in HT-12/60. However, the proposed HT-12/60 achieved significantly less FN than PT-30 in local brain area. In addition, we found a case in which PT-30 failed to depict the left CBT and low connectivity areas. These characteristics are very important for neurosurgical application because such FN of important tracts can be often fatal in intraoperative navigation. It has been reported that a neurosurgery guided by tractography images with potential FN yielded hemiparesis after surgery [4]. Therefore, we believe that our HT-12/60 method is more relevant for clinical use than PT-30. Our future work includes modification of the MR sequence to avoid the crosstalk artifact described above.

References

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