Validation of diffusion tensor imaging and tractography of the human peripheral nerve using small-diameter ex vivo phantoms

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Introduction

Diffusion tensor (DT) tractography is an established tool for visualization of neuronal tracts in the brain. Now it has been taking a new step beyond the brain and the peripheral nerve is a promising candidate for tractography. However, to our knowledge, only a few literatures are available on DT imaging and tractography of the human peripheral nerve [1-4]. Feasibility of the imaging still needs to be evaluated at each MR imager prior to the clinical application. Therefore, we aimed to develop a small-diameter phantom simulating nerve fiber bundles for validation of DT imaging and tractography of the human peripheral nerve on a clinical MR imager.

Methods

Development of simulated phantoms for peripheral nerves

Since our initial target for DT tractography was the human median nerve, we developed small-diameter flexible phantoms simulating human peripheral nerve fibers based on the method reported by Watanabe, et al [5]. These phantoms were comprised of tightly packed, 20.5-g/km, polyester filament yarns in polyethylene tubes with inner diameters of 4, 6 and 9 mm respectively. These phantoms were contained in a 6-cm-diameter polypropylene bottle with water, resembling the form of the human forearm. A stem of asparagus with several mm in diameter, an established vegetable phantom for DT tractography, was also contained as a control in the bottle.

Methods for DT imaging and tractography

We used a 3-T whole body imager (Signa HDx ver. 14, GE Healthcare, Wis, USA) and a standard 8-channel head coil for DT imaging with a single-shot echo-planar sequence (TEeff/TR = 55.4/4000 ms, 6-25 MPG directions, b value = 1000 s/mm^2, BW = 250 kHz, SENSE 2, NEX = 2-8, FOV = 16.0 cm, 12 contiguous 3-mm-thick slices, matrix = 128×128). Phantoms were placed parallel to the z-axis of the imager. After realignment of acquired images, fractional anisotropy (FA) was measured and DT tractography was created using dTV II [6]. On a transaxial FA image, a circular ROI slightly smaller than a phantom was drawn on a phantom. The mean and the standard deviation of FA were respectively recorded at each number of MPG directions, each number of excitations and each diameter of the phantoms. For fiber-tracking, tract propagation was terminated when FA fell below 0.10.

Results

Figure 1 shows the results of FA measurement of the phantom with the smallest diameter (4 mm). In all parameter settings we tested, FA values were at least 0.23 and were slightly smaller than those of the control (asparagus). Increase in NEX was found to lead to slight increase in FA. In contrast, larger FA values were found in DT imaging with 6 MPG directions than that with 15 or 25 directions, but the relatively large standard deviations (not shown in the graph) in DT imaging with 6 directions might make the measurements less robust. Fiber-tracking was successfully performed in all parameter settings and an example result is shown in Figure 2.

Conclusion

Small-diameter, flexible, ex vivo phantoms could be developed for validation of DT imaging and tractography of the human peripheral nerve. Four or more NEX and 15 or more MPG directions could provide robust results of FA measurement and fiber-tracking.

Figure 1

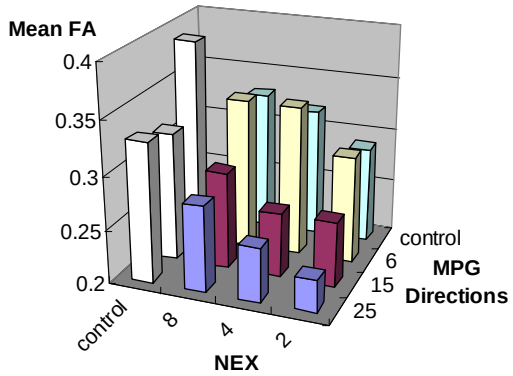

Figure 1. FA values of the 4-mm-diameter phantom are expressed as a 3D column graph against numbers of excitations and MPG directions. White columns are FA values of the control (asparagus stem) against numbers of MPG directions at fixed numbers of excitations (8 NEX), and light green columns are those against numbers of excitations at fixed MPG directions (25 directions).

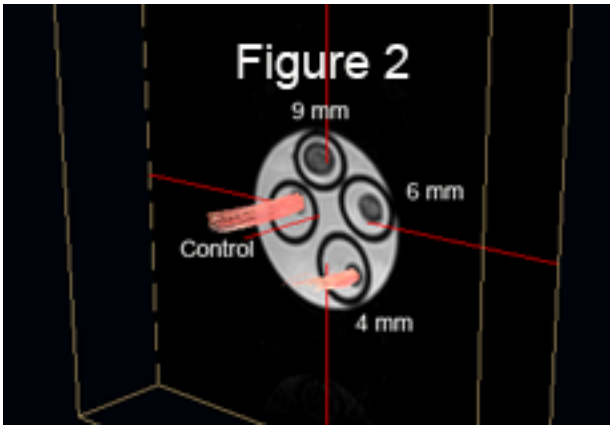

Figure 2. A representative result of fiber-tracking of the 4-mm-diameter phantom (and the control) with 15 MPG directions and 4 NEX. Tractograms are displayed with orange lines and superimposed onto a non-diffusion-weighted image. The cross-sections of 9- and 6-mm-diameter phantoms are shown as gray ovals.

References

[1] Massner J, et al. Proc. 15th ISMRM. [2] Kabakci N, et al. AJR 2007. [3] Meek M, et al. Exp Neurol 2006. [4] Skorpil M, et al. Magn Reson Imaging 2004. [5] Watanabe M, et al. Radiat Med 2006. [6] dTV II, available at http://www.ut-radiology.umin.jp/people/masutani/dTV.htm