Effect of Acquisition Parameters on the Diffusion Visualization and Quantification of Peripheral Nerves: Diffusion Tensor Imaging to Identify and Quantify Human Nerves in Forearm

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Introduction:

Much effort has gone into the visualization of peripheral nerves on MRI for improved diagnosis of nerve pathology in humans [1-3]. Recent preclinical studies have suggested the utility of specific diffusion tensor imaging (DTI) parameters in assessing peripheral nerve injury and repair [4-6]. DTI allows further enhancement to visualizing the nerves by exploiting the greater water diffusional anisotropy in nerve relative to the surrounded tissues. However, both qualitative and quantitative measures with DTI strongly depend on the scanning parameters for data acquisition. The objective of this study is to investigate the effect of spatial resolution, number of diffusion gradient encoding directions (DGED), and number of repetitions on the visualization and quantification of peripheral nerves in human forearm in a group of healthy volunteers.

Materials and Methods:

Five healthy volunteers were included in this study. MRI scans were performed on a 3 T scanner (Achieva, Philips Medical Systems, Best, Netherlands). An 8-channel flexible small extremity coil (INVIVO corp, Orlando, FL) was used for improved SNR. DTI data sets were acquired with different number of DGED (42, 21 and 7), different in-plane resolution (1x1mm^2, and 1.8x1.8mm^2), and different number of repetitions (4, 2, and 1) to investigate the effect of those scanning parameters on the visualization and quantification of the nerves. All the images were acquired in the axial plane with TR=5000ms, TE=78ms, and b=1000s/mm^2. Short tau inversion recovery (STIR) images of the forearm were acquired as a reference. The DTI data were processed by the advanced view DTI package provided by Philips. After correcting for the eddy currents, the fractional anisotropy (FA) was calculated. A region of interest (ROI) was carefully placed on the FA map to obtain average FA values for each slice. Oblique views (cross-sections of 3D volumetric data) were generated from a stack of axial slices using multi planar reformatting. The nerve course was displayed using maximum intensity projection (MIP) images. The FAs with different scanning schemes for median and ulnar nerves were compared using the student's t-test.

Results:

FA maps at higher spatial resolution (1x1mm^2 Fig 1a) allowed visualization of the superficial radial, median, and ulnar nerves consistently on all the scans, whereas only ulnar and median nerves were clearly visualized at lower spatial resolution (1.8x1.8 mm^2 Fig 1c). The images with smaller number of repetitions even with higher spatial resolution did not clearly delineate the course of any of the nerves. In particular, the course of the radial was discontinuous (Fig 1d). The visualization of the nerves was not affected by the number of DGED, provided adequate SNR is maintained by increasing the number of repetitions for scans with smaller number of DGED (Fig 1a&b). The average FA values derived from DTI imaging with 42 DGED, 2 repetitions, and 1x1 mm^2 in-plane resolution are 0.762±0.036, 0.832±0.042, and 0.692±0.078 for ulnar, median and superficial radial nerve, respectively. Statistically significant differences in the FA values were observed in the FA values with different number of DGED. Statistically significant differences in the FA values are also observed between scans with 1 and 4 repetitions with fixed 21 DGED and 1x1 mm^2 resolution. Also, significant dependence of the FA values on the in-plane spatial resolution was observed with 42 DGED and 2 repetitions. These results are summarized in Fig. 2. In this study, we did not compare the FA values of the radial nerve acquired with different scan parameters because the radial nerve which is very small is not visualized clearly at lower resolution and lower SNR.

Discussion and Conclusion:

We believe that these are the first studies that systematically evaluated the effect of various acquisition parameters on the visualization and quantification of the diffusion anisotropy on the peripheral nerves. Our results indicate the visualization and the quantification of the diffusion anisotropy of forearm nerves is strongly influenced by the SNR, spatial resolution, and number of diffusion gradient encoding directions. Our results also suggest that smaller number of encoding directions and low SNR bias the estimation of FA values. Finally, the results of these studies help optimize the DTI protocol for peripheral nerves.

Reference

[1]Aagaard BD, et al, Neurosurgery 2003; 53:199-203. [2]Andreisek G, et al, Radiographics 2006; 26:1267-1287. [3]Filler A, Neurosurgery 2009; 65:A29-A43. [4]Lehmann HC, et al, Experimental Neurology 2010; 223: 238–244. [5]Sheikh KA, Experimental Neurology 2010; 223: 72–76. [6]Stein D, et al, JMRI 29:657–662 (2009).

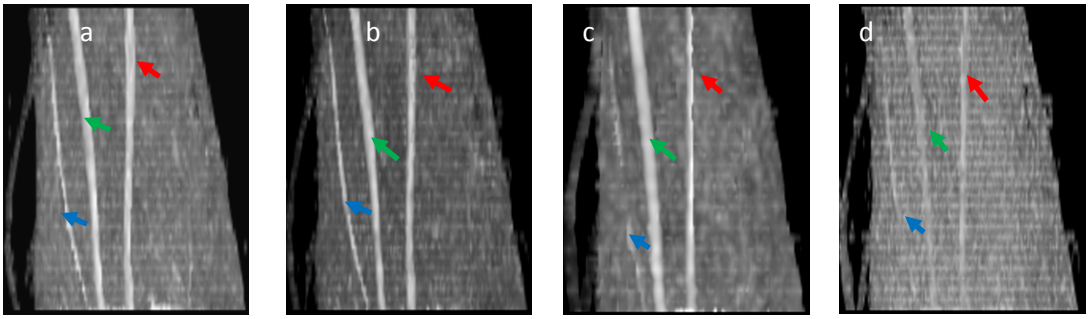

Figure 1: Oblique sagittal MIP images of FA maps of left forearm acquired with different spatial resolution, different number of diffusion gradient encoding directions (DGED) and repetitions: (a) spatial resolution (1x1 mm^2), 42 DGED, and 2 repetitions; (b) spatial resolution (1x1 mm^2), 21 DGED, and 4 repetitions; (c) spatial resolution (1.8x1.8 mm^2), 42 DGED, and 2 repetitions; (d) spatial resolution (1x1 mm^2), 21 DGED, and 1 repetition. The diffusion weighted images are acquired with 8 channel flexible small extremity coil. Median (green arrow), ulnar (red arrow) and superficial radial nerves (blue arrow).

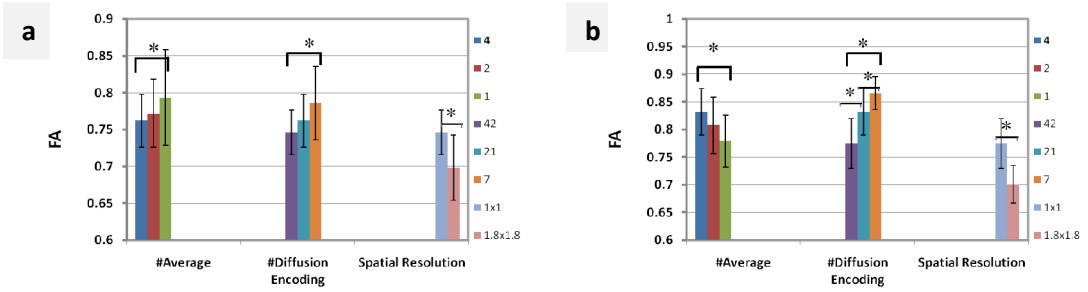

Figure 2: Dependence of the fractional anisotropy (FA) of (a) ulnar (b) median nerves in forearm on the number of diffusion gradient encoding directions (42, 21, and 7), number of repetitions (4, 2, and 1), and in-plane spatial resolutions (1x1 mm^2, and 1.8x1.8 mm^2). * indicates statistically significant differences.