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Diffusion tensor imaging of sural nerves

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Introduction Diffusion tensor imaging (DTI) is a promising clinical modality for early detection of nerve damage. DTI is used to depict structured water movements within tissues especially in nerve fibers whose orientation is of particular interest in the disease progression. In the affected areas, such as sural nerves in the lower legs and ankles, the diffusion of tissue water loses directionality due to the loss of fiber density. The molecular water mobility in normal nerve tissues exhibits a pronounced directional dependence that coincides with cellular structures. The diffusion processes are more strongly facilitated along the elongated fiber than other directions and the diffusion coefficient is found to be significantly higher in the direction of a nerve fiber. The anisotropic movement of water molecules described by fractional anisotropy (FA) which can be computed from diffusion tensors. Nerve fractional anisotropy (FA) is the quantitative indices in determining the degree of integrity of nerve myelination. The localization of the sural nerve and measuring diffusion parameters have been problematic due to the small size and limited signal to noise ratio (SNR). The aim of this study is to develop an optimal MRI protocol for quantitative DTI analysis of the sural nerves in diabetic patients. We present the anatomical localization and the DTI study of the sural nerve using 15 diffusion gradients.

Methods *MRI data* were acquired on a 3.0 T Philips Achieva MR scanner (Philips Medical Systems, Best, The Netherlands). *Anatomical localization:* T2-weighted MRI provided a distinguishable contrast between blood vessels and the sural nerve. The nerve was localized using turbo spin echo sequence in axial and coronal acquisition with 0.5(AP)x0.5(RL)x2(FH) mm3 and 0.5(FH)x 0.5(RL)x 1(AP) mm3 voxel resolutions, respectively.
DTI data with 15 gradient directions were acquires using a single shot EPI sequence in the coronal slice direction. Imaging parameters were; TR/TE=7000/62, acquisition voxel resolution= 2.34 (FH)x 0.6 (LR)x 0.5 (AP) mm3, total scan time = 12:26 minutes.
Image processing and registration For computation of FA values, images were transferred and processed using both Philips ViewForum 3D work stations and an independent software written in Digital Image Processing Laboratory (DIPL). To determine accurate localization of the nerve, we mapped diffusion images onto the anatomical T1 and T2-weighted anatomical MRI volume data. The image registration was performed using a fully automated 3D registration package, Mutual Information Automated Multimodality Image Fusion (MIAMI Fuse©) software (Kim 1997; Meyer 1997). A rigid-body 3D transformation with scaling provided adequate degrees of freedom.

Results The optimal resolution in the coronal direction, 0.5 (AP) x 2 (FH) mm^2, inplane, and 0.6 mm (RL), in slice direction, was effective in reducing the partial volume effect for the size of the nerve, ≈ 1 mm in diameter, from low calf structures. The SENSE factor of two, reduced the distortion artifacts. We have developed a baseline FA measurement protocol from healthy normal subjects by applying 15 directional DTI in the coronal orientation angulated to approximately parallel to the nerve. The proximity and shape of the sural nerve were identified by radiologists in the T1 and T2-weighted MRI anatomical images. The volumetric FA map (green hue) was registered with the T2-weighted MRI volume to locate the corresponding anatomical reference as shown in two selected slices in Fig 1. The regions of increased anisotropy along the sural cutaneous nerve is presented. Table 1 lists FA values computed using DTI from four normal subjects. The values are average of intensities in a segmented area from the selected FA map, [0, 1], registered to the anatomical T2-weighted volume data. The mean of FA values from four normal subjects, 0.533, 0.684, 0.599, 0.481, was 0.574 (stdev=0.0877).

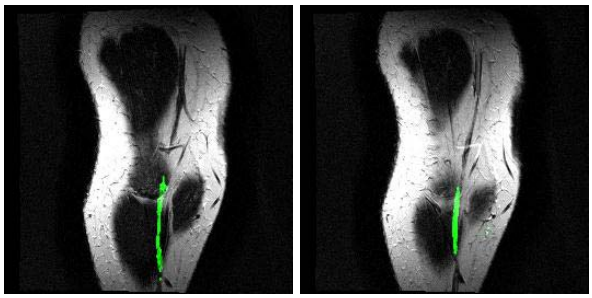

Fig.1 Fractional Anisotropic maps from DTI measurements demonstrates a linear region of increased anisotropy shown as a high signal intensity structure, along the anatomically identified sural cutaneous nerve. FA map is co- registered with the T2-weighted MRI.

Conclusions The localization of the sural nerve and measuring diffusion parameters may be problematic due to the small size and limited signal to noise ratio (SNR). Several imaging parameters, slice orientation, angulation, phase encoding direction and gradient directions impact the localization of the nerve in DTI. The challenging aspect of imaging the sural nerve is that (1) the size of the nerve (≤1 mm in diameter) is less than mostly used diffusion image resolutions (1-2 mm in-plane and 2-4 mm in slice direction), (2) its superficiality and proximity to a vein make MRI localization difficult, (3) like all EPI acquisitions distortion artifacts are large in proximity to the ankle due to magnetic field differences. Coronal slice acquisition is advantageous for the finer resolution in AP and RL direction. The phase encoding direction was along the nerve (FH direction) in which the SENSE factor was applied since the limited 2 mm resolution, the lowest in three directions, was more tolerable in the longitudinal direction.

References **1.** Meyer, C.R., et al., Med.Img.Analys, 1997, 3, p195; **2**. Kim, B., et al., NeuroImage, 1997, 5: p. 31;

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