Diffusion Tensor Imaging of the Forearm's Nerves

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Introduction

While MRI has been widely used for the study and assessment of the central nerve system (CNS), the peripheral nerve system (PNS) has received relatively little attention, at least partly, due to susceptibility induced artifacts and the small volume of the nerves. The main problem facing PNS imaging is rooted in the narrow structure of the limbs, resulting in a large boundary layer. Therefore the problem of susceptibility induced artifacts appearing due to the passage of the magnetic field through the different mediums and distorting almost all the relevant data, was the first to overcome.

In this study we have used diffusion tensor imaging (DTI) to obtain images of the median and ulnar forearm's nerves in 14 healthy subjects as well as to extract the fractional anisotropy (FA), and the principal diffusivities values of the median nerve proximally to, and within, the wrist's carpal tunnel (CT). We expected to see differences in the parameters at these different locations because of the anatomical tract the fibers go through; from a free, lose, straight forward tract proximally to the CT, to a further stretched, tight, dense fiber bundle when passing through the CT. To avoid the susceptibility induced artifacts we used here a sleeve filled with an inert fluid having susceptibility matched to that of water [1].

Methods

14 healthy volunteers were scanned in a GE 3T MRI scanner using a general purpose flex coil. In order to overcome the susceptibility induced artifacts we have designed a sturdy nylon made sleeve filled with Flourinert (FC-77, 3M) which the forearm easily slips into (see Figure 1) [1]. Flourinert is a proton free liquid containing only fluorinated oil which is undetectable by the scanner. Once placed in the liquid filled sleeve, the large susceptibility differences between the forearm's tissue and surrounding air, are greatly reduced [1]. The DTI protocol included TR/TE=10000/81 ms; FOV=14x14 cm^2; matrix=64x64 (up-sampled to 128x128); slice thickness of 3 mm with no spacing and 6 gradient directions (xy, xz, yz, -xy, -xz, y-z) with b value of 1,000 s/mm^2. Each volunteer underwent 10 repetitions of the DTI protocol and a single FSE T2 (with and without fat saturation) scan with the following parameters: TR/TE=3650/75 and same slice locations matrix resolution as the DTI protocol but with doubled matrix resolution. SPM (UCL, London, UK) was used in order to realign all repetitions to the first b=0 volume. The gradient transformation matrix was calculated and an in-house Matlab © was used to obtain the following maps: FA, ADC, $D_{//}$, $D_{\perp}$.

Figure 1

Results

Figure 2 shows 3-cuts (horizontal, vertical and in-plane) through the same forearm depicting both median (red) and ulnar (yellow) nerves. As seen in Figure 2 the appearance of susceptibility induced artifact in the image is greatly reduced (compare top, FA maps to bottom T2 maps). Both nerves are seen very clearly in FA maps, but show only very low signal in the T2 weighted images. DTI analysis revealed that the FA values at the CT are significantly elevated compared to those found proximally to the CT (by 9%, $p<0.03$). The ADC values change as well to a reduced 15% at the CT. The parallel diffusivity ($D_{//}$) is reduced by 9% while the radial diffusivity ($D_{\perp}$) is reduced by approximately 29%. All numerical data is summarized in Table 1.

Table 1	proximally to CT	At CT	p value
FA	0.55±0.1	0.6±0.12	<0.03
ADC	8.7±2.9	7.4±2.8	<0.02
$D_{//}$	1.5±0.46	1.36±0.45	<0.02
$D_{\perp}$	0.42±0.14	0.3±0.19	<0.02
SNR	18.6±9.5	15.7±8.5	n.s.

Discussion and Conclusions

We show here that by standard DTI protocol we resolve the two main forearm's nerves – the Median and the Ulnar. Proximally to the CT the diffusion characteristics of the median nerve are similar to those found in the CNS. However, at the CT the ratio between the parallel and radial diffusivities is higher than the CNS's usual value of 3 and reaches 4.5, indicating a highly directional flow. At the CT, where the fibers are closely packed, the FA increases mainly as a result of radial diffusivity reduction (lower $D_{\perp}$ values at the CT), indicating higher packing of the fibers.

With the use of a high-field magnet, a stronger gradient system and technical devices to reduce susceptibility artifacts, imaging of peripheral nerves using DTI is now feasible. Using the protocol described above the median and ulnar nerves can be well quantified and characterized using DTI. This could have tremendous effects for studying many related forearm nerve pathologies, such as the carpal tunnel syndrome, as well as being the beginning of a vast study and assessment of the rest of the PNS.

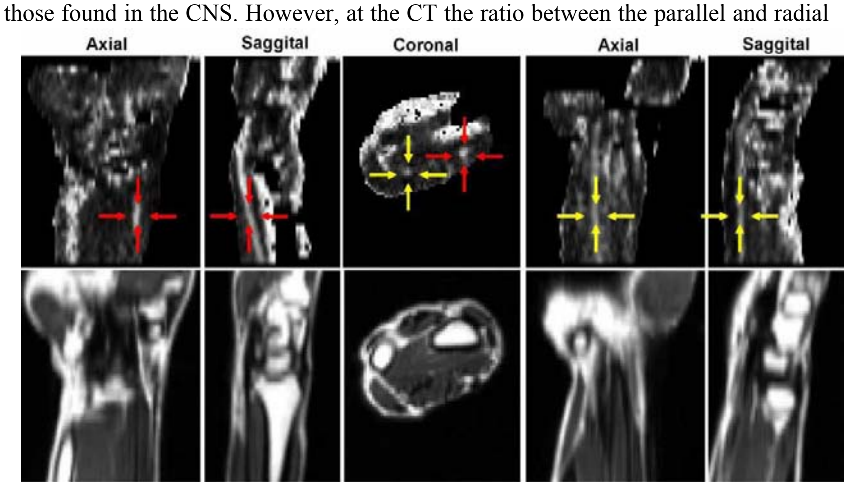

Figure 2: FA (top row) and T2 (bottom row) of 3-cuts through the forearm. The left 3 columns indicate the position of the median nerve (red) while the right 3 columns indicate the position of the ulnar nerve (yellow).

References

[1] Neufeld A, Assaf Y, Navon G. 'Homogeneity Helmet' for correcting susceptibility artifacts in f-MRI. Proc. Intel. Soc. Magn. Res. Med., 11, 750, 2004.