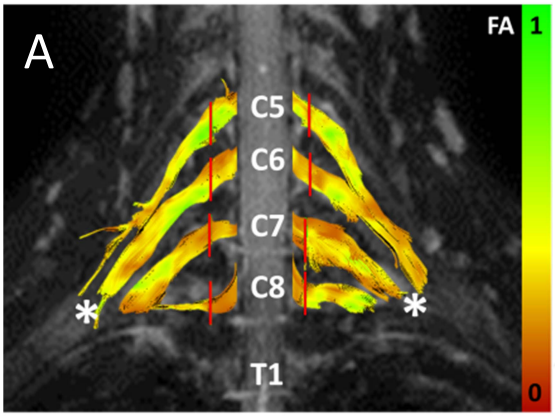
Semi-Automated DTI Measurement of the Brachial Plexus using Tracts of Interest

Jos Oudeman[1], Martijn Froeling[1,2], Gustav J Strijkers[3], Mario Maas[1], Dennis F R Heijtel[1], Bram F Coolen[1], Camiel Verhamme[4], Matthan W A Caan[1], Marianne de Visser[4], and Aart J Nederveen[1]

[1]Radiology, Academic Medical Center, Amsterdam, Noord Holland, Netherlands, [2]Radiology, University Medical Center, Utrecht, Utrecht, Netherlands, [3]Biomedical NMR, Department of biomedical engineering, Eindhoven University of Technology, Eindhoven, Brabant, Netherlands, [4]Neurology, Academic Medical Center, Noord Holland, Netherlands

Introduction: Diagnosis of acquired immune mediated diseases affecting peripheral nerves like chronic inflammatory demyelinating neuropathy and multifocal motor neuropathy often relies on electrophysiological conduction studies. However, the proximal part of the brachial plexus (above Erb's point) cannot be easily studied with these techniques. For this reason one of the supportive diagnostic criteria is an increased signal intensity on T2-weighted MRI, associated with a diffuse nerve swelling of the brachial plexus [1]. It has been suggested that Diffusion Tensor Imaging (DTI) derived parameters may be more sensitive for detecting immune mediated disease activity in the brachial plexus [2], and thus DTI may be a promising diagnostic tool. Currently, measuring DTI derived parameters along the plexus is mostly done by manual placement of several Regions of Interest (ROI) along the roots and trunks. This method is time consuming, difficult in small structures and only reliable when performed meticulously. A faster and more reliable automatic method is needed to improve the applicability in clinical practice. In several DTI studies of the brain it has been shown that instead of multiple manual ROI placements along the assumed fiber path of interest, tractography based on only one or two seeding ROIs can be used to obtain so-called tracts of interest (TOI) [3]. We hypothesized that the TOI approach could also be implemented in DTI analysis of the brachial plexus, thus leading to faster and robust measurements. The **aim** of this explorative study was to develop a TOI based method for DTI measurements along the roots and trunks of the brachial plexus using solely one single seeding ROI at each root of the plexus.



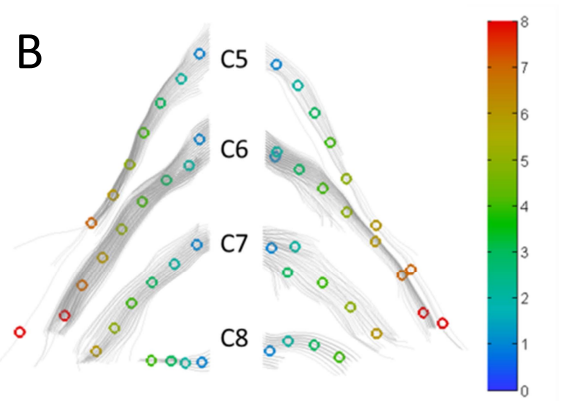


Figure 1A: MPR of the 3D VISTA image with superimposed the reconstructed tracts with corresponding seeding ROI in red. The fiber tracts are color coded for FA. The asterisks are placed at Erb's point.

Figure 1B: Reconstructed fiber tracts (C5-C8) with the used sample points along the roots and trunks.

Methods: A healthy 30 year old subject was scanned on a Philips Ingenia 3.0T scanner. The FOV was covered with 16 coil elements by combining 8 elements of the 16-element body-array coil, 4 elements of the posterior part of the 16 channel head array coil and 4 elements of the spine array coil. For anatomical reference a 3D VISTA sequence with a diffusion sensitive iMSDE preparation was used to visualize the nerves [2]. The following imaging parameters were used for DTI: axial SE-EPI; FOV: 320x200 mm2; TE/TR: 77/7943 ms; matrix size 128x80; slices: 60; voxel size: 2.5x2.5x2.5 mm^3; gradient directions: 32; b-value: 800 s/mm^2; Fat suppression: SPIR; scan duration: 9 min 39s.
Sequence parameters for the 3D VISTA were: FOV: 220x320x150 mm^3; (TEeff)/(TR) 61/2500 ms, TSE factor: 100, echo spacing: 4.0 ms, voxel size: 1×1×1mm^3, fat suppression: SPAIR; scan duration of 4 min 12s.
DTI data was processed using a custom-built toolbox for Mathematica 9.0 [2] and tractography was performed using the vIST/e toolbox [3]. Seeding was done with 1 ROI per root per side, placed just outside the myelum in the sagittal plane of the 3D VISTA images; stop criteria: min FA 0.1, fiber angle of 10 degrees per step of 0.15 voxel and a minimum fiber length of 3 cm. Fibers were exported and analyzed using a custom-built toolbox in Matlab [4]. A predefined number of sample points per root and trunk were automatically evenly placed along the arc length of the reconstructed fibers (8 sample points for C5-C6, 6 for C7 and 4 for C8). Mean MD and FA values per resulting cluster were computed.
Results and Discussion: The roots and trunks of the brachial plexus (C5-C8) were reconstructed with a good anatomical representation of the brachial plexus till Erb's point (Figure 1A) with the use of only one seeding ROI at per root. The sample points were correctly placed along the tracts, starting at the root (Figure 1B). DTI derived parameters of left and right side were rather similar. Occasionally, more variation within single MD- or FA-profiles was observed (Figure 2). The mean and SD values of FA were in agreement with literature (Table 1)[3]. The less reliable results for C8 and absence of T1 can be explained by a low signal to noise ratio, which is due to its location near the apex of the lungs. With further optimization of the DTI protocol and the use of probabilistic tractography, results can further improve.
Conclusion: DTI measurements of the brachial plexus with the use of tracts of interest showed to be feasible and can be used in multi-subject comparative studies into immune mediated diseases. Future work will include reproducibility studies in healthy volunteers and optimization of the cluster size in the trunks to obtain precise diffusion parameter estimates.
References: [1] Van Schaik IN, Eftimov EFNS MMN guideline 2010;301:295–301 , [2] Tagliafico A et al. Eur Radiol 2011;21:1764–71[3] Yoneyama et al. Magn Reson Med Sci 2013;12:111–9 [4] M.W.A. Caan, EEE TBME 2010;58(9):2431-40 , [5] M. Froeling et. al. J Magn Reson Imaging 2012;36:237–48.

	FA mean (SD)		MD mean (SD)	
	Left	Right	Left	Right
C5	0.38 (0.10)	0.42 (0.10)	0.99 (0.22)	0.89 (0.14)
C6	0.37 (0.02)	0.46 (0.04)	1.24 (0.04)	1.11 (0.06)
C7	0.35 (0.01)	0.37 (0.04)	1.23 (0.060	1.26 (0.05)
C8	0.42 (0.02)	0.27 (0.03)	0.99 (0.07)	1.21 (0.09)

Table 1: FA and MD (10^{-3} mm/s^2) averaged over the complete tract

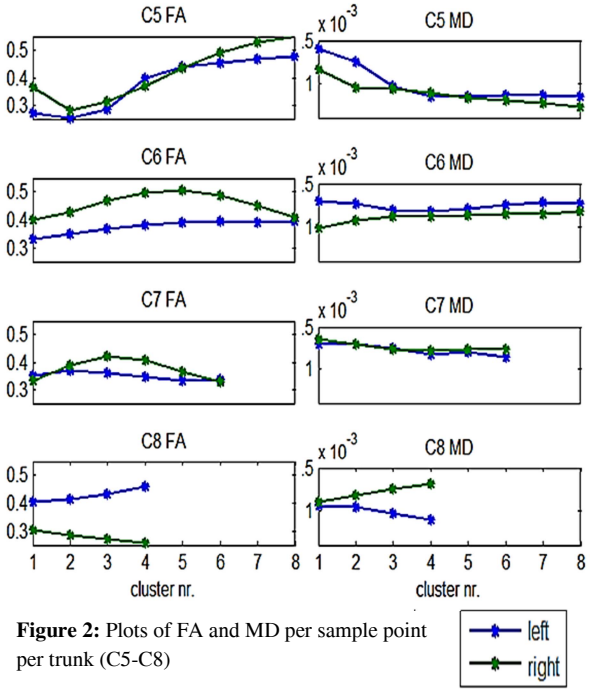


Figure 2: Plots of FA and MD per sample point per trunk (C5-C8)