Triple-echo steady state T2 mapping and high resolution axonal bundle assessment of the median nerve in healthy volunteers and patients with carpal tunnel syndrome at 7Tesla

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Target Audience Musculoskeletal Radiologists and Physicists

Purpose Recently the triple echo steady state (TESS) relaxometry has been introduced which allows fast and accurate T_2 and T_1 mapping.[1] Moreover, using a dedicated 12-channel receive wrist coil and a high resolution, a proton density Fast Spin Echo sequence with fat suppression (PD-TSE fat sat) at 7 Tesla (T) may allow sufficient resolution to determine nerve structures on a axonal bundle level.[2] The aims of this preliminary study were (1) to determine normative T_2 values measured by TESS of the median nerve at several locations proximally and within the carpal tunnel in healthy volunteers and patients with idiopathic carpal tunnel syndrome (CTS) and (2) to determine the numbers of axonal bundles within the median nerve (fascicles) with a PD-TSE fat sat in these subjects.

Methods Six volunteers (three female, 3 male; 28 ± 9yrs), and three patients (three female, 38 ± 17yrs) with idiopathic CTS were included in the study. Measurements were performed on the left and right wrist in three volunteers, only on one wrist in three volunteers (total n=9) and on the affected wrist in patients (n=3). The local ethics commission approved this study and all volunteers and patients gave written, informed consent. All subjects underwent MR examinations at 7 T (Siemens AG, Siemens Healthcare, Erlangen, Germany) using a dedicated 12-channel receive array with a volume transmit wrist coil (RAPID Biomedical GmbH, Rimpar, Germany) consisting of two sequences: axial PD-TSE fat sat (TA: 5:34) and axial 3D-TESS (TA: 5:44). Two reader assessed T_2 values by Region of Interest (ROI) analysis and counted the number of fascicles independently. T_2 values were assessed on 18 sections in four different regions (two proximally and two within the carpal tunnel). One section with the best delineation of the nerve and its fascicles was chosen for fascicle number count.

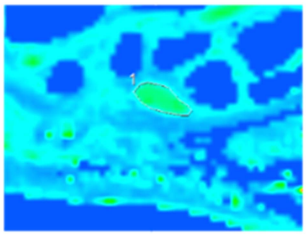

Fig. 1. Enlarged T_2 map of a healthy volunteer within the CT (mean T_2 was 22.2)

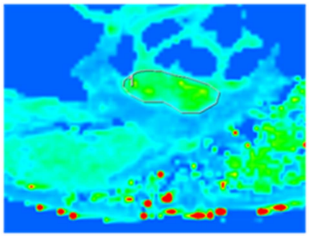

Fig. 2. Enlarged T_2 map of patient with CTS and swollen median nerve (mean T_2 was 28.9)

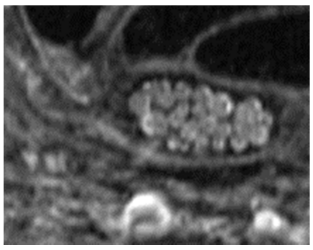

Fig. 3. Enlarged image of the median nerve with clearly visible fascicles

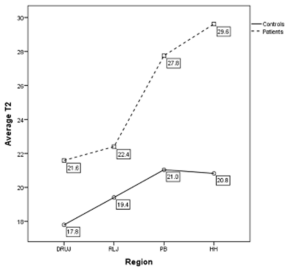

Fig. 4 Region dependent T_2 values

Results T_2 relaxation time values are presented using mean +/- standard deviation. In order to compare T_2 values a two way mixed model ANOVA and Bonferroni post hoc tests were used. Fascicle counts are presented as median and range (minimum to maximum). Intraclass correlation (ICC) was used to assess rater agreement. A p-value equal to or less than 0.05 was considered statistically significant. Quantitatively the overall mean T_2 values of patients with CTS were significantly higher for the median nerve over its entire course in comparison to healthy subjects (P = 0.008). Three out of four regions in CTS-patients revealed significantly higher T_2 values in comparison to healthy volunteers with a strong increase in the carpal tunnel and lower differences out of the tunnel (Table 1, Fig. 4). ICC for T_2 assessment was 0.97 indicating an almost perfect agreement. Fascicle count of the median nerve ranged from 14 to 23 with a median of 19 in all subjects. (Table 2). The ICC for fascicle counts was 0.81 indicating an almost perfect agreement.

Table 1 T2 values of the MEDIAN NERVE

	WN	DRUJ	RLJ	PB	HH
T_2 (SD) healthy	**19.77 (2.44)**	**17.90 (1,95)**	**19.40 (2.53)**	**21.04 (2.82)**	**20.82 (3.58)**
T_2 (SD) patient	**25.34 (2.48)**	**21.59 (1.64)**	**22.40 (3.24)**	**27.75 (3.82)**	**29.62 (3.69)**
t-test	0.008	0.032	0.137	0.030	0.024

Acronyms: *WN* Whole Nerve *DRUJ* Distal Radio Ulnar Joint *RLJ* Radio Lunate Joint PB Pisiform Bone *HH* Hook of Hamate

Table 2 FASCICLE count of the MEDIAN NERVE

	V1	V2	V3	V4	V5	V6
Reader 1	**16**	**17**	**20**	**19**	**15**	**14**
Reader 2	**17**	**19**	**19**	**20**	**17**	**15**

	V7	V8	V9	P1	P2	P3
Reader 1	**21**	**21**	**23**	**20**	**18**	**21**
Reader 2	**22**	**23**	**22**	**19**	**17**	**18**

Acronyms: *V* healthy Volunteer *P* Patient

Discussion T_2 mapping of the median nerve with TESS at 7 T allows for fast biochemical assessment of nerve structures and demonstrated the ability to distinguish between healthy and damaged nerve structures within the carpal tunnel. T_2 values of the median nerve assessed with TESS depend on the anatomical location. Region specific T_2 values within the carpal tunnel might be used to diagnose CTS. Axial PD-TSE with fat suppression at 7 T allowed for assessment of nerve structures on the fascicular level within normal examination times in vivo.

Conclusion 3D TESS and ax PD-TSE fat sat at 7T provide fast and reliable morphological and biochemical assessment of the median nerve in healthy volunteers and patients within a clinically acceptable scan time opening a variety of new possibilities (e.g. fascicle assessment before nerve transplantation, image-supported diagnosis of CTS).

References

1.Heule R, Ganter C, Bieri O. Triple echo steady-state (TESS) relaxometry. Magnetic resonance in medicine : official journal of the Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine 2014;71(1):230-237.

2.Raghuraman S, Mueller MF, Zbyn S, et al. 12-channel receive array with a volume transmit coil for hand/wrist imaging at 7 T. Journal of magnetic resonance imaging : JMRI 2013;38(1):238-244.