Reproducibility of diffusion tensor imaging in human forearm muscles

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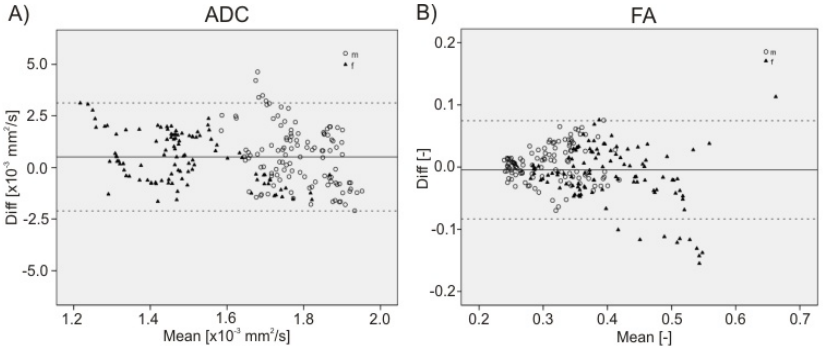
Introduction: In the last years diffusion tensor imaging (DTI) has proven to be a useful research tool to study skeletal muscle e.g. muscle architecture [1], injury [2], denervation [3] or regeneration [4]. In this study we investigated the reproducibility of DTI applied to human forearm muscles.

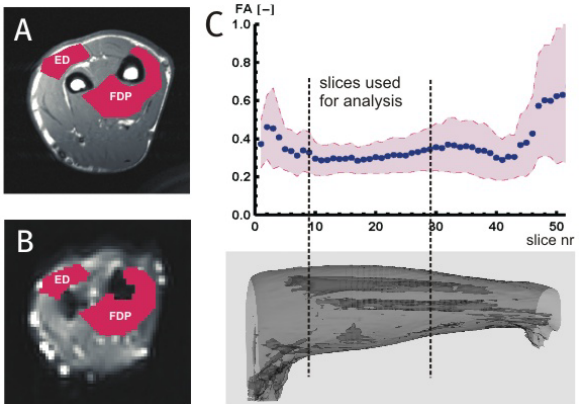
Specific aims: 1) Investigate the feasibility of DTI in the complex muscular system of the human forearm using a fast clinical protocol. **2)** Determine the reproducibility of DTI parameters (eigenvalues (λ1, λ2 and λ3), ADC and FA).

Methods: MRI: The right forearm of 10 healthy volunteers (5 male, 5 female, age: 22.7 ± 1.9 years) was measured on two different occasions (measurements 1 and 2) using four flexible surface coils on a 3T Philips Intera scanner. T1 imaging: T1w RARE (FOV: 200x200 mm^2, Matrix 400x400, slice thickness: 6 mm, 50 slices, TR/TE: 550/12 ms, time: 13 min 42 s). DTI measurements: SE-EPI (FOV: 200 x 200 mm^2, matrix size: 79x79 with 112x112 reconstructed matrix, slice thickness: 6 mm, 50 slices, 16 directions, TR/TE: 8 s/48 ms, SPAIR fat suppression, NSA: 2, b=400 s/mm^2, time: 7 min 40 s). Diffusion weighted images were registered to their corresponding un-weighted image.
Analysis: For each dataset mean values for the eigenvalues (λ1, λ2 and λ3) the ADC and FA were calculated per slice. Next 20 slices in the middle of the arm were selected for analysis (see figure 1). The proximal head of the radius was used as anatomical landmark to mach the two datasets. Eigenvalues, ADC and FA were also calculated separately for 2 ROIs, one in the Extensor digitorum (ED) and the other in the Flexor digitorum profundus (FDP). Statistical analysis was done using SPSS16.

Results and discussion: The mean values of the eigenvalues (λ1, λ2 and λ3), ADC and FA were constant within the selected slices (figure 1c). A slice by slice comparison between measurement 1 and 2 was done using Bland-Altman plots (figure 2). They show that the differences between the two measurements remained within the 1.96 times SD bandwidth. Strong differences between male and female for the ADC were observed. Table 1 shows that both the ED and FDP had comparable mean values for the DTI parameters, but those of the FDP have a lower coefficient of variation and a higher reproducibility index than those of the ED, possibly because the FDP is mainly surrounded by other muscle tissue whereas the ED is partly adjacent to fat and skin layers.

Conclusion: We have shown that DTI of the human forearm is possible, that it can be preformed in a clinical setting with a fast measurement protocol (7 min 40 s) and that the derived parameters are reproducible within a certain range.





▲ **Figure 1:** ***(A)*** *ROIs selecting the ED and FDP muscles visualized on high resolution T1 weighted scan.* ***(B)*** *ROIs selecting the ED and FDP muscles visualized on b=0 image.* ***(C)*** *top: FA as a function of the slice number (mean and SD) of one subject, bottom: 3D reconstruction of the forearm from the T_1 images. Selected slices used for analysis are*

▼**Table 1:** *Mean values, standard deviation, coefficients of variation (CV) and reproducibility index (RI) for the diffusion tensor parameter of two different muscles, the ED and FDP. λ1, λ2, λ3 and ADC are given in 10^{-3} mm^2/s, FA is dimensionless.*

A. Extensor Digitorum (ED)			
	Mean ± SD	**CV(%)**	**RI**
λ1	2.06 ± 0.11	7.8	0.30
λ2	1.45 ± 0.11	12.9	0.37
λ3	1.15 ± 0.11	15.4	0.35
ADC	1.55 ± 0.10	10.7	0.33
FA	0.30 ± 0.03	19.0	0.11

B. Flexor Digitorum Profundus (FDP)			
	Mean ± SD	**CV (%)**	**RI**
λ1	2.22 ± 0.19	8.1	0.35
λ2	1.52 ± 0.17	8.6	0.25
λ3	1.21 ± 0.14	11.9	0.27
ADC	1.65 ± 0.16	9.0	0.29
FA	0.31 ± 0.02	8.9	0.05

References:
[1] *Heemskerk AM et al. MRM 53: 1333-1340, 2005.*
[2] *Zaraiskaya T er al. J MRI 24: 402-408, 2006.*
[3] *Zhang J et al. Exp Neurol 212: 448-457, 2008.*
[4] *Heemskerk AM et al. Rad. 243: 413-421, 2007.*

◄ **Figure 2:** *Bland-Altman plots comparing measurements 1 and 2 of the* ***(A)*** *ADC and* ***(B)*** *FA. Data points represent means of individual slices of the whole muscle volume, female subjects are indicated with (▲) and male subjects with (○). The dotted line represents 1.96 times the standard deviation*