DIFFUSION TENSOR IMAGING OF THE HUMAN CALF - COMPARISON BETWEEN 1.5T AND 3.0T - PRELIMINARY EXPERIENCE

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Introduction:

Diffusion tensor magnetic resonance imaging (DT-MRI) (1) is a useful method to noninvasively study the structure of organs such as the brain, spinal cord, kidney, heart or skeletal muscle. The potential usefulness of DT-MRI in diagnosing neurological disorders (2) was pointed out and use of diffusion MR is well established in brain imaging. Against this, outside the brain diffusion is more difficult because of respiratory motion artifacts and the short T2 values of body tissue and thus leave less room for the diffusion gradient pulses. The aim of this study was to compare DT-MRI of the human calf at 3.0T and 1.5T in the same healthy volunteers using the same imaging protocol with similar imaging parameters in order to calculate and to determine a number of quantitative parameters to characterize diffusion anisotropy in organized tissue.

Theory and Methods:

Five healthy adult volunteers were included in this study. All volunteers underwent MR imaging at 3.0T and 1.5T. Imaging on both MR systems was performed utilizing a standard quadrature knee send and receive coil and using the same imaging protocol. Four routine diffusion-weighted spin-echo EPI pulse sequences (with different b values in six and eleven directions) were applied to collect series of 2D images through the calf muscles of each subject. A DTI-studio program (Johns Hopkins University, Baltimore, Maryland, USA) was used for image analysis and tensor calculations. The following calculations were made:

- The three eigenvalues of the diffusion tensor $(\lambda_1 \geq \lambda_2 \geq \lambda_3)$
- Knowing λ's, the trace of the diffusion tensor Tr(D) was calculated: Tr(D) = $\lambda_1 + \lambda_2 + \lambda_3$
- The fractional anisotropy was calculated as: FA = $\frac{\sqrt{3\left(\lambda_1 - \langle D\rangle\right)^2 + \left(\lambda_2 - \langle D\rangle\right)^2 + \left(\lambda_3 - \langle D\rangle\right)^2}}{\sqrt{2\left(\lambda_1^2 + \lambda_2^2 + \lambda_3^2\right)}}$
- The relative anisotropy (RA) was calculated: RA = $\sqrt{\left(\lambda_1 - \langle\lambda\rangle\right)^2 + \left(\lambda_2 - \langle\lambda\rangle\right)^2 + \left(\lambda_3 - \langle\lambda\rangle\right)^2} / \sqrt{3\langle\lambda\rangle}$
- The volume ratio (VR) was also calculated: VR = $\lambda_1\lambda_2\lambda_3 / \langle\lambda\rangle^3$

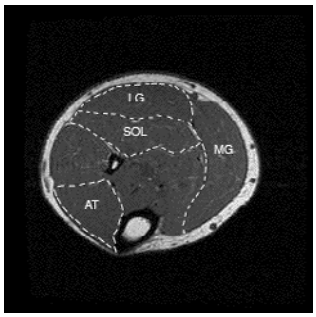

Fig.1

The three eigenvalues reflect the physical pathways of water diffusion within the muscle tissues. Diffusion pathways of water within the skeletal muscles. The highest value λ_1 represents the diffusion along the long axis of the muscle fiber, while λ_2 and λ_3 represent diffusion in directions perpendicular to this long axis.

The mean diffusivity (D) characterizes the overall mean-squared displacement of molecules and the overall presence of obstacles to diffusion. To obtain an overall evaluation of the diffusion in a region one must avoid anisotropic diffusion effects and limit the result to an invariant, (e.g. independent of tissue orientation with respect to the static magnetic field B_0). The FA and RA are used to provide information about the eccentricity of the diffusion ellipsoid. The FA scales from 0 to 1, where 0 represents the perfect sphere (isotropy) and 1 represents an infinite cylinder (complete anisotropy). VR represents the ratio of the ellipsoid volume to the volume of a sphere of radius, its range is from 1 (isotropic diffusion) to 0, so that some authors prefer to use (1-VR).

Regions of interest (ROI) were specified using the high contrast axial T1-weighted spin-echo sequence for four different muscles. The analyzed muscles were the lateral gastrocnemius (LG), medial gastrocnemius (MG), soleus muscle (SOL) and anterior tibialis (AT) (Fig. 1). All quantitative assessments of LG, MG, SOL and AT indices muscle groups were defined by manually traced regions of interest each encompassed approximately 300 pixels. The same ROI at the same muscle (LG, MG, SOL, AT) was measured three times for each diffusion -weighted spin-echo EPI pulse sequence (b=300 s/cm^2, b=500 s/cm^2 and b=700) .

	Tr(D)			FA		
b-value	300	500	700	300	500	700
1.5T	4.44±0.05	4.56±0.05	4.52±0.03	0.20±0.06	0.24±0.07	0.22±0.03
3.0T	4.45±0.04	4.39±0.02	4.57±0.02	0.21±0.04	0.24±0.05	0.24±0.02
	RA			**VR**		
b-value	300	500	700	300	500	700
1.5T	0.18±0.04	0.20±0.03	0.21±0.04	0.05±0.03	0.06±0.03	0.05±0.03
3.0T	0.19±0.03	0.19±0.03	0.22±0.02	0.05±0.02	0.05±0.01	0.06±0.02

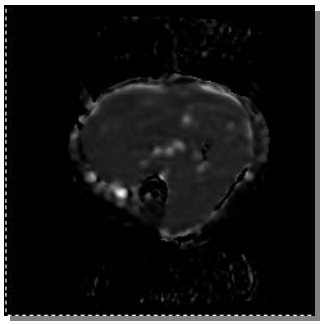

Fig. 2

Results:

In the table mean values and SD are given for all muscles. The Tr(D) (Fig. 2 ; 3T, b=300) is reported in 10^{-5}cm^2·s^{-1}; mean ± SD. There was no significant difference between calculated parameters at 3T and 1.5T (p=0.34). The eigenvalues, Tr(D), FA, RA and VR were also calculated separately for each muscle (MG,LG,AT,SOL) (1.5T; 1.83±0.04, 1.44±0.06, 1.21±0.07 and 3T; 1.90±0.04, 1.44±0.05, 1.23±0.05). There was no significant difference between the different muscles (p=0.12).

Conclusion:

The study demonstrates useful parameters to perform DT-MRI at 1.5T and 3.0T. DT-MRI at 1.5 and 3.0T provides in vivo validation of quantitative structural analysis of human skleletal muscle and provides information about muscle fiber orientation and architecture of the diffusion pathway.

References

1. Basser PJ, Mattiello J, LeBihan D. MR diffusion tensor spectroscopy and imaging. Biophys J 1994; 66:259-267.
2. Le Bihan D, Breton E, Lallemand D, Grenier P, Cabanis E, Laval-Jeantet M. MR imaging of intravoxel incoherent motions: application to diffusion and perfusion in neurologic disorders. Radiology 1986; 161:401-407.