Diffusion Tensor Imaging of the human aortic wall: an ex-vivo study

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Target Audience: Biomedical engineers/scientists/clinicians interested in the MRI of the aorta.

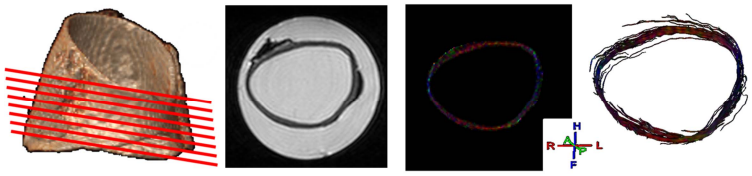
Purpose: Diffusion Tensor Imaging (DTI) is an noninvasively technique that provides information on tissue microstructure by measuring the diffusion of water molecules[1]. However, DTI scans typically have low spatial resolutions for constraints on signal-to-noise ratio (SNR) and various kind of artifacts[2]. Currently, only one DTI study is reported on fresh and frozen porcine aorta[3], while no data on human aorta are available. We aimed here: 1) to explore the use of high resolution DTI scans for studying the architecture of the human aortic wall *ex-vivo* using a whole-body MRI scanner, 2) to investigate the influence of scan parameters on DTI quantitative indices.

Methods: Whole fresh samples of dilated ascending aorta were collected from five patients undergoing elective surgical repair and placed into a custom-designed chamber filled with physiological hydrogel. MRI acquisitions were performed on a 3T Philips Ingenia MRI scanner. An anatomical T1-weighted dataset was acquired with a 3D gradient echo (GRE) sequence with TE/TR 3.4/7.8, flip angle 8°, 90 slices, matrix 128×128, voxel size 0.5×0.5x0.5 mm^3. DTI images were acquired using a fat-saturated multi-shot EPI sequence (EPI factor 9) to reduce T2* blurring and Nyquist ghosting effects. Eight slices are acquired orthogonal to the vessel. Four DTI protocols with similar acquisition times (about 2h30') were adopted. FOV and TE/TR were kept constant to 60×60 mm^2 and 70/4176 ms respectively, while different scan parameters were evaluated. In particular, spatial resolution, b-value, number of diffusion gradient directions and number of signal averages (NSA) were varied according to Table 1. Concerning DTI post-processing, eddy current correction was applied and the diffusion tensor was calculated. Fiber tractography was performed using a deterministic algorithm with the following stopping criteria: minimum fractional anisotropy (FA) 0.1, max angle change 45°, minimum fiber length 10 mm. Quantitative assessment of the different protocols was carried out by evaluating 1) the SNR of the images without diffusion gradients (b0-images), 2) the SNR of diffusion-weighted (DW) images, 3) the mean diffusivity (MD), 4) the radial diffusivity (RD) and 5) the fractional anisotropy (FA).

Protocol	Resolution [mm]	b-value [mm^2/s]	No. diffusion directions	NSA	Acq. time
P1	0.65x0.65x1.5	1000	15	16	2h59'
P2	0.65x0.65x1.5	500	32	8	2h36'
P3	0.75x0.75x2.0	500	32	8	2h02'
P4	0.75x0.75x2.0	1000	15	16	2h32'

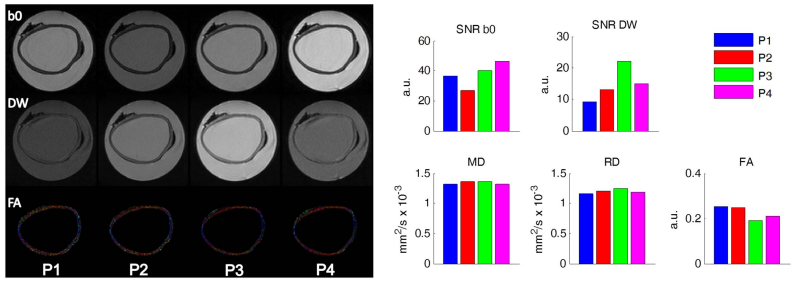
Table. 1: Scan parameters of the DTI protocols.

Results and Discussion: Fig. 1 shows representative results obtained in a sample of aortic tissue. Fig. 1a shows the location of the DTI slices cross-referenced with the 3D volume rendering of the sample acquired with the T1-weighted GRE sequence. The b0-image of a mid-slice shown in Fig. 1b exhibits high SNR and absence of ghosting artifacts. The directions of the primary eigenvector of the diffusion tensor (Fig. 1c) are mainly distributed on the in-plane directions, i.e. left-right (red) and feet-head (blue) due to the coronal orientation of the acquisition plane. This pattern highlighted a circumferential direction of the diffusion that was confirmed by the fiber distribution obtained by the fiber tracking algorithm (Fig. 1d). The four DTI protocols showed good image quality without significant artifacts (Fig. 2a). The SNR of the b0-images is explained by the different voxel resolution (0.63 mm^3 for P1-P2, 1.12 mm^3 for P3-P4) and NSA. As expected, the SNR of DW images increased for lower b0-values (P2-P3). Non-significant differences were found in the MD and RD indices, while mean FA values were found lower for scan protocols with lower spatial resolution (P3-P4). Color-coded FA maps (Fig.2 a) showed similar pattern of the predominant diffusion direction, mainly distributed on the in-plane directions. However, in terms of SNR and reduced acquisition time, protocol P3 gave the best results.



(a) (b) (c) (d)

Fig. 1: a) 3D volume rendering of the aortic sample with cross-references of DTI slices; b) b0 image of the DTI scan; c) color-coded fractional anisotropy map; d) fiber tracking results.



(a) (b)

Fig. 2: a) Mid-slice images acquired using four DTI scan protocols: b0-image (upper row), average of the DWI images (middle row) and color-coded FA map (bottom row). b) Quantitative analysis of the different DTI protocols in terms of SNR and diffusion indices.

Conclusion: This study is the first demonstration of DTI acquisition of the human aortic wall on a clinical 3.0T whole-body scanner. An optimal acquisition protocol was established for obtaining the fiber distribution of the aortic tissue. The capability to visualize the entire 3D fiber architecture in a non-destructive way could provide a novel and valuable information on the pathological state of the vessel wall. However, further investigation is necessary to correlate quantitative DTI results with histological analysis.

References: [1]Le Bihan D et al.J Magn Reson Imaging 2001:13(4), 534-546. [2]Mukherjee P. et al. AJNR Am J Neuroradiol 2008: 29(5), 843-852. [3]Flamini V et al. Med Eng Phys. 2013:35(6), 765-776.