Effect of Gradient Resolution in Diffusion Tensor Imaging on the Appearance of Multiple Sclerosis Lesions at 3T

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Introduction:

Diffusion Tensor Imaging (DTI) has emerged as a powerful tool in Magnetic Resonance Imaging (MRI) of Multiple Sclerosis (MS). DTI quality and the variations of the derived scalar maps, such as Fractional Anisotropy (FA) and Apparent Diffusion Coefficient (ADC) is a function of the number of gradients and b-values employed [1]. In clinical settings, the number of diffusion gradients is limited due to time constraints. In this work, the quality of lesion appearances is analyzed with respect to the diffusion gradient resolution focusing on automatic lesion localization and duration of the scans.

Materials & Methods:

Data acquisition: Preliminary assessment of 10 MS patients from a dataset of 200 patients was conducted using an 8-channel head coil in a 3T MRI system (Achieva, Philips Medical Systems). For each image, three different DTI scans with different gradient resolutions were acquired along with a T_{2W}-FLAIR image. Two of these scans used scanner's preset gradient schemes and settings with one b=0 s/mm^2 volume and 6 and 15 diffusion weighted volumes respectively. The last scan consisted of ten b=0 s/mm^2 volumes, ten b=300 s/mm^2 volumes and 60 b=1100 s/mm^2 volumes and default scanner settings were altered for better scan times. Intermediary b-values were included to observe the effects on CSF-white matter interfaces. Scan times were 2 minutes, 4 minutes and 8 minutes based on the experimental designs. The gradient scheme was selected according to [2]. Each DT image was acquired with: SENSE=2, FOV=256x256mm, slice thickness-3mm, no gap, matrix size=128x128 and 60 axial slices.

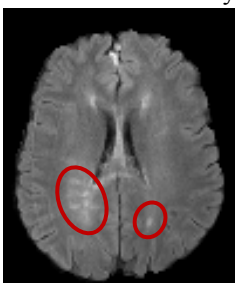

Figure 1. Transverse T_{2W}-FLAIR image of an MS patient (lesionloactions are indicated with red circles.)

Processing & Analysis: Diffusion weighted images were corrected for motion, Eddy-currents and susceptibility induced EPI distortions, aligned to the T_{2W}-FLAIR images and resampled to 1.5x1.5x1.5mm^3 resolution. Diffusion tensors were computed using non-linear regression [3]. Lesion Regions of Interests (ROIs) were selected from T_{2W}-FLAIR images and these ROIs were used to extract FA and ADC distributions from different DTI images. The stability of the distributions was analyzed with respect to gradient resolutions to justify the extra scan times. Additionally, a pre-trained automatic lesion segmentation routine was run on the DTI images to observe the effects of DTI quality on lesion localization. This segmentation process was only based on tensor images and not the derived scalar fields.

Results: Quality differences between different gradient schemes were both visually and quantitatively significant. Figure 1 displays a transverse T_{2W}-FLAIR image of the brain of an MS patient with a red circle and an ellipsoid indicating the chosen lesion locations. Figure 2 displays the corresponding FA and ADC images for each gradient scheme (7, 16 and 80 volumes). The lesion in the ellipsoid is better delineated on FA images with increasing number of gradient directions, providing sufficient quality with 16 volumes and even sharper edges for 80 volumes. The small lesion is almost not visible with 6 directions and become clearer with increasing gradient directions. The large lesion does not cause a significant increase in ADC for the low directional scheme and appears only clearly in the 80 directional scheme. The same results were seen on ADC maps for the small lesion. FA and ADC distributions are summarized in Table 1. Table 1 shows that FA means and standard deviations decrease with increasing number of directions. However, the biggest decrease is in kurtosis meaning more of the variance is due to infrequent extreme deviations with low number of gradients. Contrary to [1], trace changes are relatively small but the same behavior is observed with kurtosis, indicating stability of the high-gradient distributions. Automatic segmentation on lesions confirmed an increase in "correct labelling" by 3% and 4.5% using the 16 and 80 directional data relative to 6 volumes (60% classification accuracy).

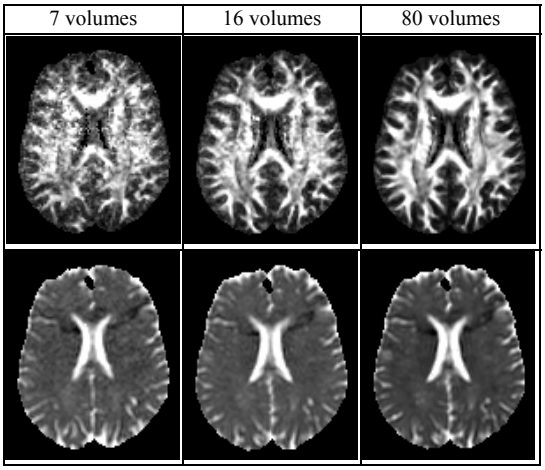

Figure 2. FA/ADC maps of an MS patient with different gradients.

	Mean	Stdev	Kurtosis
7-FA	0.372	0.149	1.71
16-FA	0.317	0.146	1.47
80-FA	0.316	0.139	0.49
7-ADC	919.5	206.3	5.04
16-ADC	961.8	205.3	3.98
80-ADC	953.7	230.9	3.28

Table 1. Lesion FA and trace distributions.

Discussion: Increasing the diffusion gradient resolution allows a better localization of MS lesions. An 80-volume DTI scan with a scan time of 8 minutes is tolerable for MS patients and improves the quality of the derived scalar field distributions.

References: 1. D. K. Jones, et. al., "The Effect of Gradient Sampling Schemes on Measures Derived From Diffusion Tensor MRI",2008. 2. D.K. Jones, et. al., "Optimal Strategies for Measuring Diffusion in AnisotropicSystems by Magnetic Resonance Imaging",1999. 3. http://www.tortoisedti.org.