Radial Fractional Anisotropy Mean and Radial Mean Diffusivity Mean: New metric in the Study of Spinal Cord Tissue

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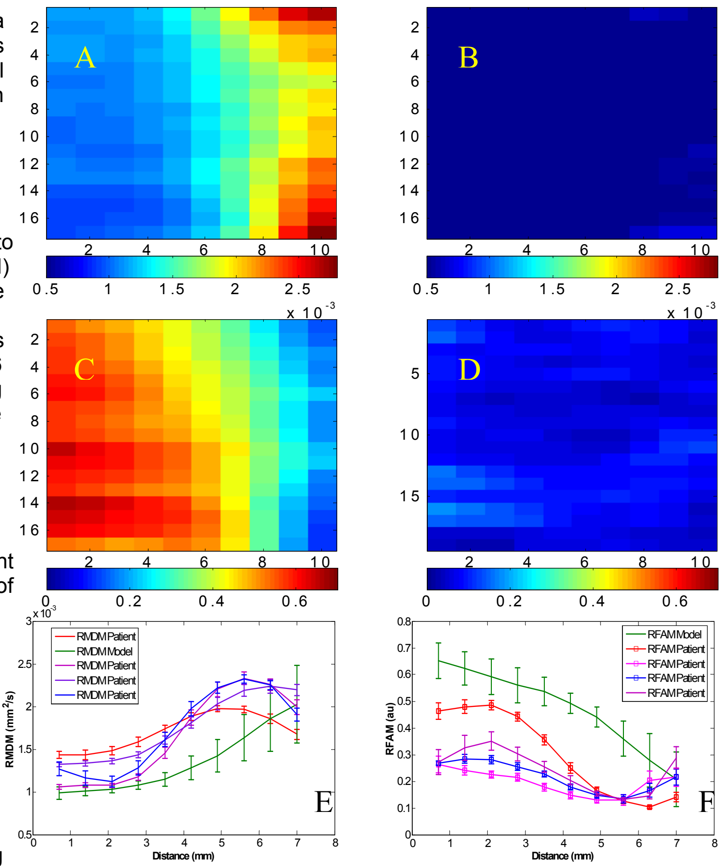
Introduction: Conventional magnetic resonance imaging in the Spinal Cord (SC) is often insufficient to diagnose and assess the stage and progression of ailments. Diffusion Tensor Imaging (DTI) and its ability to delineate the motion of water molecules and subsequently white matter tracts has become more important during the last years. Nevertheless, due to the lack of resolution and the poor signal to noise ratio, it is still one of the big challenges in clinical MR research. In this abstract a new approach to quantitatively assess SC tissue is presented. This new approach is based in the combination of quantitative information obtained from DTI; Fractional Anisotropy (FA) and Mean Diffusivity (MD); taking advantage of the singular geometry of the SC.

Theory: To better understand the state and organization of SC tissue, a combination of FA and MD quantitative data is proposed in this paper. This new metric has been designed to take advantage of the cylindrical geometry of the spinal cord. A combination of FA; that provides information about the organization of the tissue within each voxel and MD; which provides information about the freedom of the water molecules in each voxel is presented. With this new approach an improvement in the quantitative detection of lesions and abnormalities that break the natural arrangement of the SC is presented. Radial Fractional Anisotropy Mean (RFAM) measures the changes in FA values as a function of the distance to the centre of the cord. Similarly, Radial Mean Diffusivity Mean (RMDM) values measures the changes in MD as a function of the distance to the centre of the SC.

Methods: MR images were obtained from a total of 10 controls: 5 males and 5 females with an average and standard deviation age of 29.7 ± 7.6 years. Images of 4 patients were obtained 5 months after surgery (including implantation of metallic instrumentation) and following the approval from the Research Ethics Board along with informed consent of the patients. The 4 patients presented different levels of cervical stenosis. Imaging was performed on a 1.5 T Siemens Quantum symphony system with actively shielded magnetic field gradients. The DTI acquisition was performed using an axial spin-echo echoplanar parallel grappa diffusion weighted imaging sequence with acceleration factor 2; 12 non collinear gradient directions were applied with two b-values (b=0 and b=600 s/mm^2) field of view 180 x 180 mm; 17 slices and a thickness of 5 mm. Mean Diffusivity and Fractional Anisotropy of the SC were obtained after processing the images with the fsl package. RFAM and RMDM values were obtained as the mean Fractional Anisotropy and Mean Diffusivity values as a function of distance to the centre of the SC, which was manually selected for each slice. A 10 pixels radius circle centered in that point of the FA map is used as ROI to generate both the RFAM and RMDM. The RFAM and the RMDM are obtained after calculating the mean of all the FA and MD values equidistant from the center of the ROI for every slice and then plotting them versus the distance respectively. Mean Diffusivity Map (MDM) and Fractional Anisotropy Maps (FAM) are obtained after collecting the RFAM and the RMDM vectors for all the slices.



Results and Discussion: Figures A and **B** show the MDM and the standard deviation of the MDM obtained after averaging all the control MDM data. On the y-axis we have the slice number, going from 1 (vertebrae C2- vertebrae C3) to 17 (top of vertebrae C7). The distance in mm from the centre of the cord is represented on the x-axis. **Figures C** and **D** show the FAM and the standard deviation of the FAM obtained after averaging all the control FAM data. As expected the images acquired from patients were highly affected by the presence of the metallic implants. Therefore, measurements were taken above and below the level of the lesion. **Figures E** and **F** represent the RMDM and RFAM of the 4 patients compared to the RMDM and RFAM model obtained from the healthy volunteers (in green). The standard deviation of the MDM (**Figure B**) and FAM (**Figure D**) show that there is little statistical difference when averaging healthy controls. Therefore, the FAM and MDM data model obtained from the healthy controls can be used as reference value for healthy looking SC in terms of FA and MD respectively. Using it as a reference, the data obtained from patients were compared to the healthy data model in **Figures E** and **F.** As it can be seen in **Figure E,** the mobility of water molecules in patients is significantly higher than in the average RMDM model obtained from the controls, indicative of an environment more suitable for brownian motion probably due to a lack of white matter structure, as suggested by the low RFAM results obtained from the patients shown on **Figure F;** where the RFAM of the patients are plotted versus the average RFAM model obtained from the healthy controls.

Conclusion: This technique comes as an approach to solve the lack of resolution and SNR characteristics of the spinal cord DTI studies. Taking advantage of the cylindrical geometry of the cord, a second subset of quantitative parameters RFAM and RMDM is defined to improve our understanding of the structural organization of the SC. A model based on the data obtained from 10 healthy controls for RFAM and RMDM has been implemented. RMDM and RFAM obtained from SC stenotic patients after surgery is statistically different from those values derived from the healthy volunteers.

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