# Radial Fractional Anisotropy Mean and Angular Fractional Anisotropy Mean: New Tools in the Diagnosis and Assessment of Spinal Cord

**A. Cárdenas-Blanco[1,2], H. Westwick[1,2], K. A. Moran[3], and E. C. Tsai[2,4]**

[1]Division of Neuroscience, Ottawa Health Research Institute, Ottawa, Ontario, Canada, [2]University of Ottawa, Ottawa, Ontario, Canada, [3]Medical School, University of Ottawa, Ottawa, Ontario, Canada, [4]Neurosurgery, Ottawa Hospital, Ottawa, Ontario, Canada

**Introduction:** Conventional magnetic resonance imaging in the Spinal Cord (SC) is often insufficient to diagnose, asses the stage and progression of ailments, and correlate clinical observations to imaging. During the last years, Diffusion Tensor Imaging (DTI) has become the preferred tool to analyze white matter properties in SC by showing a displacement of the white matter tracts at the level of the pathological lesion. In this abstract a new approach to quantitatively assess SC tissue is proposed. This approach is based in the measurement of Radial Fractional Anisotropy Mean (RFAM) and Angular Fractional Anisotropy Mean (AFAM) values which depict the changes in fractional anisotropy mean values as a function of the distance from the centre of the SC and the angle respectively.

**Theory:** Fractional Anisotropy (FA) measures the fraction of the diffusion tensor that can be ascribed as anisotropic diffusion[1]. In normal white matter tissue, the movement of intracellular water is restricted in the direction perpendicular to the length of the axon rather than parallel to it due to the elongated cylinder like geometry of axons, therefore causing a proportional increase of FA values. Sadly, due to the presence of tumors or lesions, the natural arrangement of the SC is disrupted. As a consequence of that disruption the restriction on the water molecules movement can be broken therefore reducing the FA values. This abstract proposes a new method to measure the disruption in neural tissue by analyzing FA maps from a new perspective. RFAM measures the changes in FA values as a function of the distance to the centre of the SC whereas AFAM measures the distribution of FA values as a function of their orientation with respect to the centre of the SC.

**Methods:** MR images were obtained from a total of 6 patients and 1 control after receiving approval from the Research Ethics Board along with informed consent of the patients. Using radiological and pathological reports, patients were diagnosed with 3 neoplastic lesions: hemangioblastoma, astrocytoma , teratoma; two SC cysts; one hemorraghic intramedullary lesion. 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. Fractional anisotropy maps of the SC were obtained after processing the images with the fsl package. RFAM values were obtained as the mean Fractional Anisotropy value 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 the AFAM. The RFAM is obtained after calculating the mean of all the FA values equidistant from the center of the ROI for every slice and then plotting them versus the distance. AFAM is obtained by plotting in polar coordinates, slice by slice, the ROI FA values versus the angle defined between the line defined by each pixel and the center of the ROI and the line defined by the center of the ROI and its ventral end.

**Results and Discussion:** Figures A and C show two AFAM maps both at the fourth cervical level. Figure A presents the AFAM map of the study control. From that image, it can be inferred that in our control, high FA values (FA>0.5) are homogeneously distributed whereas low FA values (FA<0.2) seem to be concentrated at particular angles. In Figure C, AFAM maps of a patient, which presented a cyst, before (magenta) and 5 months after surgery (blue) are presented.  In Figure C it can be seen that a) there is an increase of fractional anisotropy after surgery (blue) with respect to the AFAM map acquired before surgery (magenta) although none of those maps present the level of anisotropy shown in Figure A. That increment is especially localized between 120 and 160 degrees, which could respond to the improvement in sensitivity of the patient's arm clinically diagnosed after surgery. This increment in FA values in the region of 120 to 160 degrees corresponds with the region of ascending spinal cord tracts of the fasciculus cuneatus, responsible for relaying sensory information from the arm.  Figure B shows the RFAM obtained before (magenta) and after surgery (blue) from the same patient compared to the RFAM values correspondent to the control (black). This graph shows a significant increase in RFAM values closer to the centre of the SC after surgery, which is indicative of tissue re-arrangement. Figure D compares all RFAM data obtained from the different cervical injuries to the control (black). Where we can see that in all those cases, the RFAM value is able to detect abnormalities in the tissue (not expected AFAM and RFAM low values) due to pathologies such as: cysts, intra medullary lesion and astrocytoma. RFAM and AFAM were also sensitive to detect abnormalities in the case of non-cervical lesions.

**Conclusion:** Although this study is in its preliminary stage, the results suggest that RFAM measurements can be used to diagnose tumors and lesions in the SC and also to follow up the patient evolution during time after surgery. AFAM is especially sensitive to the localization of decreased fractional anisotropy in the SC indicative of ailments and abnormalities in specific sensory and motor tracts in the SC, indicating which regions are most affected by the abnormal pathology. The results presented are based on the tissue disruption detected by a decrease in FA values and rearrangement of the tissue after surgery detected by an increase on the FA values. Therefore these methods are especially helpful in quantifying both the degree of damage and the degree of improvement before and after surgical intervention respectively.
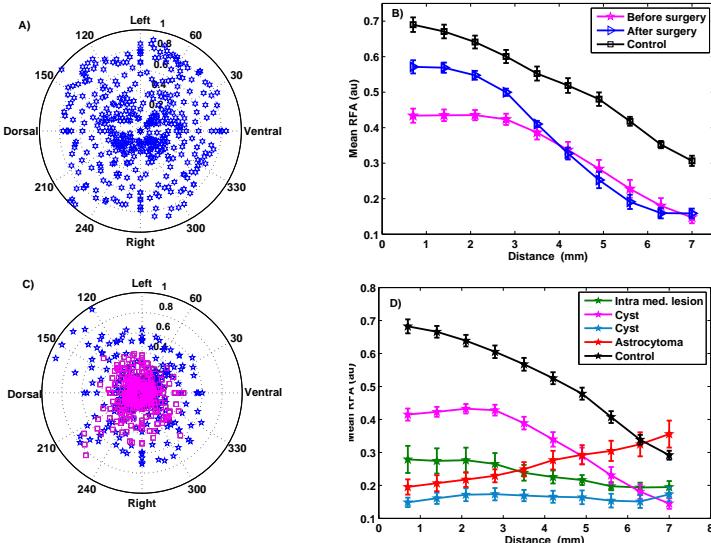
**Reference**: **1)** Basser and Pierpaoli JMR series B, 111,209-219