Analysis of superior longitudinal fasciculus and arcuate fasciculus with diffusion tensor images of dyslexia patients

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Introduction

The arcuate fasciculus (AF) contained within the superior longitudinal fasciculus (SLF) connects eloquent cortex putatively involved in written word processing; abnormalities in composition or structure in children with dyslexia may be studied using DTI [1,2]. Fractional anisotropy (FA) from DTI was used to detect the changes of AF integrity. We hypothesized that the morphology and FA of AF could be correlated with reading capability. The goal of the study was to reveal the morphological and volumetric changes of AF and SLF between dyslexia and normal reading children and locate the position where FA was most affected within AF.

Methods

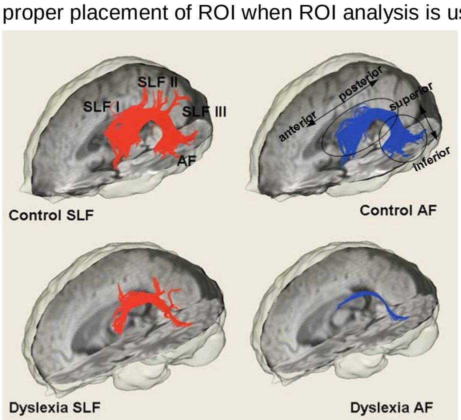
Data acquisition: Six dyslexic (age: 10-15 yrs) and 6 normal readers (age: 11-14 yrs) were scanned on a 3T Philips Achieva MR system. DTI data were acquired using a single-shot echo-planar imaging (EPI) sequence with SENSE parallel imaging scheme (SENSitivity Encoding, reduction factor = 2.5). DTI parameters were: FOV=256/256/112mm, in plane imaging matrix = 128 × 128, axial slices thickness = 2 mm, parallel to the anterior–posterior commissure line, 30 independent diffusion-weighted directions with b-value = 700 s/mm^2 [3], TR=8237ms, TE=74ms, 3 signal averages. Total scanning time was 13 min 30 sec. *Segmentation and relative volume measurement of SLF and AF:* Fiber tracking [4] was used to segment SLF and AF as shown in Fig. 1. All voxels where the fibers pass through are assigned value 1 and others 0 to obtain the segmented SLF and AF in volume data. The voxel counts of segmented SLF and AF were divided by the total brain voxel counts to calculate the relative volume. *Partitioned FA measurement:* After registering the FA images of the subjects into a template space with affine transformation, the traced AF was cut into two parts, the frontal/anterior part (Part I) and posterior/temporal part (Part II), as shown in the upper right panel of Fig. 1. Each part was further evenly divided into eight segments and averaged FA at each segment was calculated.

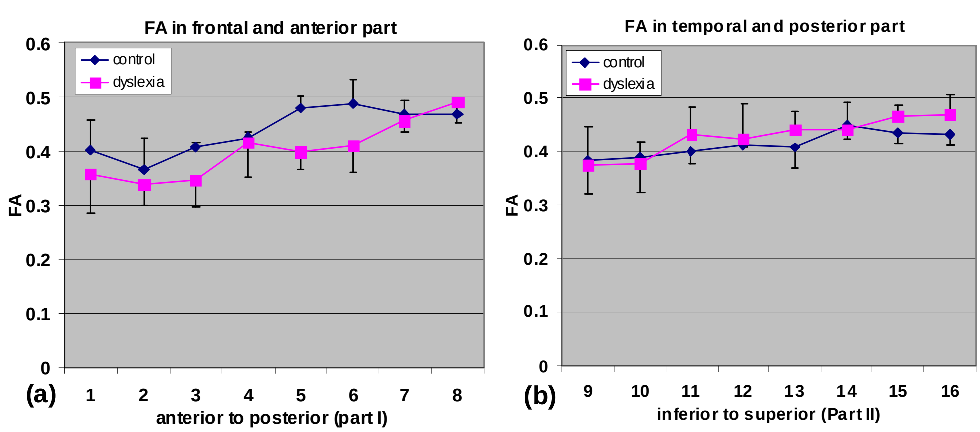
Results

As seen by visual inspection of 3D reconstructed SLF and AF in Fig. 1 the traced SLF and AF from dyslexia subjects appear smaller than those of normal readers, confirmed by quantitative measurement of the tract volumes in Table 1. However, the averaged FA values of AF and SLF in Table 1 are not sensitive enough to reveal the global structural change of the tract. From Fig. 1, Part I of AF is the frontal/parietal segment and Part II of AF is parietal/temporal. Fig. 2 reveals the local difference of the FA values between dyslexia and normal groups. Fig. 2b shows that there is little difference of FA values in each segment of Part II while larger differences in FA are seen in segments 5 and 6 of part I in Fig. 2a. The FA plots in Fig. 2 indicate that differences in FA changes are limited to the posterior portion of part I.

Discussion

DTI-based tractography suggests the SLF and AF of dyslexics are much smaller and thinner than those of normal readers which might be explained on the basis of incoherence of these tracts in the dyslexia subjects. There is no statistically significant difference between averaged FA of SLF and AF between dyslexia patients and healthy children, but in some local segments FA values are significantly smaller in dyslexia patients. This suggests that averaged FA of the whole tract is not sufficiently sensitive to the regional changes in FA. The regions of lowest FA in dyslexia subjects may dictate proper placement of ROI when ROI analysis is used. Additional data collection and statistical analysis is ongoing.





	FA	Relative Volume (10^{-3})
AF Control	$0.425_{0.023}$	$5.13_{0.53}$
AF Dyslexia	$0.412_{0.050}$	$1.53_{0.72}$*
SLF Control	$0.418_{0.031}$	$9.34_{0.53}$
SLF Dyslexia	$0.416_{0.040}$	$5.18_{0.99}$*

Fig. 1 (Upper left): The 3D reconstructed SLF and AF in a control and dyslexia patient. The AF is cut into two parts in the panel showing control AF.

Fig. 2 (Upper middle and right): (a) The local FA values in 1 to 8 segments in frontal and anterior part of control and dyslexia groups; (b) The local FA values in 9 to 16 segments in temporal and posterior part of control and dyslexia groups.

Table 1 (left): The averaged FA values and relative volumes of total AF and SLF for control and dyslexia groups. The standard deviation is listed in the lower right part of each number and asterisk indicates p values are less than 0.05 from student t-test.

References: [1] Klingberg, T, et al (2000) Neuron 25: 493. [2] Beaulieu, C, et al (2005) NeuroImage 25: 1266. [3] Jones DK et al. (1999) MRM (1999) 42:515. [4] Mori, S, et al (1999) Ann. Neurol. 45: 265.

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