Radial diffusivity measurement of the Corpus Callosum to investigate normal aging and pathological cognitive decline

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Introduction

Recently there has been growing interest for the measurement of "radial" diffusivity (rADC), i.e. the diffusion coefficient in the plane orthogonal to the direction of fibers, as it is thought to reflect myelin content (1-2). We developed a method (3) to estimate rADC in the corpus callosum (CC), which requires a very short scan time (approximately 5 minutes). The method offers about two times the sensitivity of conventional diffusion measurements in the estimation of rADC. Here we apply this method to the study of the CC of patients with dementia and of healthy subjects spanning a wide range of years of age. As white matter (WM) fibers connecting different areas of the brain cross the CC in different sections it is reasonable to assume that a reduction in myelination in a particular region of the CC reflects a reduction of myelination in the fibers crossing that particular section of the structure.

Methods

Our acquisition/estimation method (3) is based on the assumption that the investigated WM area is characterized by well directed nerve fascicles, allowing for a cylindrical symmetry description of the tensorial properties of diffusion. A simple mathematical fitting model (3) is then used to extract the rADC value from an optimized acquisition scheme, consisting of 32 diffusion measurements and 8 diffusion unweighted measurements. We studied 4 subjects with Alzheimer's disease (AD) (mean age(SD)=76(4)yrs), 6 subjects with mild cognitive impairment (MCI) (mean age(SD)=72(6)yrs), and 25 healthy subjects who were divided into 2 subgroups, depending on their age: young controls (YC) (n=19, mean (SD) age=29(5) yrs) and elderly controls (EC) (n=6, mean (SD)age=71(8)yrs). rADC was computed (see Fig.1) in 5 sagittal slices including the CC (resolution 1.4x1.4mm^2, thickness 2.7mm, the central one positioned to cross the middle of the CC itself). For each subject, three 3D-ROIs where outlined on the average b0 (diffusion unweighted) images, the first one positioned in the genu, the second one positioned in the body and third one positioned in the splenium of the CC. The ROIs covered the three inner slices (8.1 mm thickness at all) and their size was about 10 voxels on each slice (so that each ROI size was about 10x1.4x1.4x3x2.7≈160 mm^3). The mean value of rADC in each ROI was computed for all the 35 subjects ($\langle rADC\rangle^i_{region}$, $i\in\{YC\cup EC\cup MCI\cup AD\}$; region=genu, body, splenium). Correlation of all the $\langle rADC\rangle^i_{region}$ values versus age was performed among healthy volunteers ($i\in\{YC\cup EC\}$). Mean values of $\langle rADC\rangle^g_{region}$ was computed for all the 4 groups (g≡YC, EC, MCI, AD, see Table 1) and compared by t-test analysis. The $\langle rADC\rangle^i_{region}$ values were also correlated with neuropsychological scores obtained from the MCI+AD group subjects ($i\in\{MCI\cup AD\}$) using an extensive battery.

Results

A direct correlation (R=0.69; p<0.001) was found between the $\langle rADC\rangle^i_{genu}$ ($i\in\{YC\cup EC\}$) values and age (see Fig.2). No correlation with age was found for the $\langle rADC\rangle^i_{splenium}$ values and for the $\langle rADC\rangle^i_{body}$ values. T-test comparisons showed significant differences between $\langle rADC\rangle^{YC}_{genu}$ and $\langle rADC\rangle^{EC}_{genu}$ values (p<0.001). A promising trend was also found in the genu of CC for the median rADC values among all the groups (see Fig.3). In MCI and AD patients, $\langle rADC\rangle^i_{genu}$ values correlated with verbal episodic memory and semantic memory tests (R values ranging from 0.73 to 0.84).

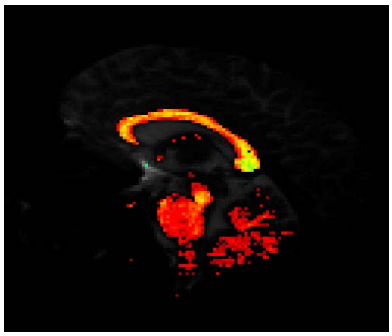

Figure 1 A map of the rADC in CC. The central slice in one YC subject.

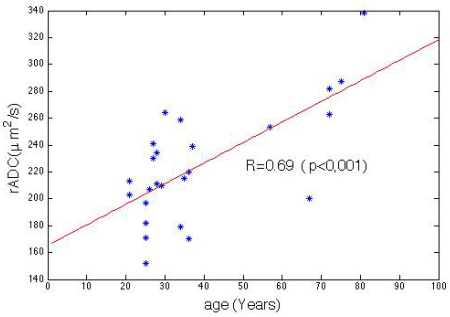

Figure 2 Correlation of $\langle rADC\rangle^i_{genu}$ values with age among the healthy volunteers.

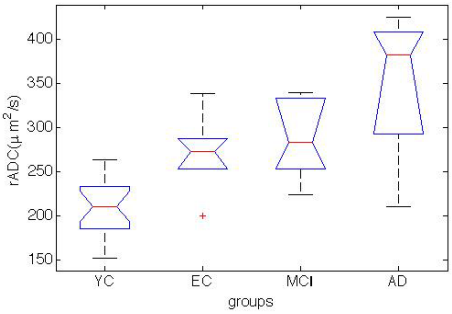

Figure 3 Box Plot of the median values of the rADC in the genu of CC among the 4 groups. (μm^2/s) in all regions and groups

Discussion

Although this should be considered only a preliminary investigation, the calculation of rADC in our sample was robust, as suggested by the low standard deviation values (see Fig.2 and Table 1). Assuming that mainly fibers connecting the frontal regions of the brain cross the genu of the CC, our results suggest that rADC is sensitive to structural changes of WM which are likely to reflect the degeneration which is known to occur with ageing and dementia in the frontal lobe. The correlations found between $\langle rADC\rangle^i_{genu}$ of the patients and neuropsychological measures suggest that this method might be employed in longitudinal studies to monitor AD evolution.

	genu	body	splenium
YC	210±30	315±35	189±37
EC	270±45	274±28	210±31
MCI	286±47	293±35	195±62
AD	350±95	252±37	229±14

Table 1. Mean ± standard deviation values of rADC (μm^2/s) in all regions and groups of cc among the 4 groups. (μm^2/s) in all regions and groups.

References

[1] Song S.K. et al. Neuroimage, 2003. 20(3): p. 1714-22
[2] Concha L. et al. NeuroImage 32 (2006) 1090 – 1099
[3] Fasano F. et al. abstract submitted at ISMRM 2007