Age-related changes in thickness, R1 and R2* values of the cortex at 7T

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Motivation: Quantitative imaging has found age-related brain changes using volumetry, relaxometry (T1, T2, T2*, etc.). Analysis on the white matter or deep gray matter has been much conducted (1); however, analysis focused on the cortex mandates high resolution imaging with adequate SNR. Such conditions can be better attained using 7T compared with lower fields. Complicated morphological structure of the cerebral cortex also impedes analysis focused on the cerebral cortex. Recently, an optimized analysis has been proposed as the HCP pipeline (2) implemented on FSL and FreeSurfer. Comparisons of multiple quantitative parameters of the cortex is expected shed light on the physiological changes. This study investigated age-related changes of the cortex using quantitative values of cortical volume, T1 and T2.

Methods: Ninety-nine healthy volunteers aged from 20 – 78 (mean 50) years old were enrolled under approval of institutional review board. MRI scans were conducted using a 7T MRI (MAGNETOM 7T, Siemens Healthcare, Erlangen, Germany) and a 1ch-Tx & 32ch-Rx coil (Nova Medical, Wilmington, MA). Scanning protocol included 3D MP2RAGE imaging (prototype sequence; TR/TE 6000/2.9ms, FA1/FA2 4/5, TI1/TI2 800/2700ms, iPAT 3, isotropic 0.7mm, scan time 9:20) 4,5 and 3D multi-echo gradient echo imaging (TR/TE1-TE4 4340/4.15-20.59ms, FA 8, iPAT 3, isotropic 0.5mm, scan time 10:26) with FID navigators for phase correction implemented based on MP2RAGE(3). T1-weighted images and T1 maps were used to compute cortical boundary using a modified HCP pipeline, and cortical thickness was derived. T2* map was calculated using linear fitting after log transformation of the signal intensity and co-registered to T1WI. Region-wise ROI (aparca2009s in HCP pipeline) values were calculated. Three quantitative values (thickness, R1 and R2*) of the cortex were linearly regressed to subject ages, and line of slopes were mapped on to the ROIs. Reliability of R1 and R2* measurements at the insula and temporal & frontal bases, and results on these areas are not discussed (4,5), although cortical thickness can be reliably evaluated (6).

Results: Figure 1 shows region-wise line slopes mapped on to the cortex. Cortical thickness showed age-related decrease in all ROIs, which was larger in the cingulate and right medial frontal area followed by lateral frontal regions. The primary sensory-motor and visual areas showed least changes. Changes in both R1 and R2* showed similar patterns with some regional differences. The frontal regions in general including the primary motor cortex was found to have larger changes than parieto-occipital regions. The cingulate showed relatively small changes. In all 3 quantitative measurements, superior temporal regions showed intermediate degree of changes.

Discussion: Frontal lobe predominance in all 3 values are considered to reflect age-related decline in higher cognitive function. Similar patterns were observed between R1 and R2* values. Both are considered to reflect amount of myelin and iron. A longitudinal study of cortical R1 in healthy aged subjects at 3T showed increase in R1 values, which was considered attributable to increased iron concentrations (7), which is similar in R2*. Cortical iron deposition is related to neuron and tissue damage, and the differences are detected as changes in cortical thickness. It can be considered reasonable that 3 quantitative values had similar tendency, but large difference was observed at the cingulate and primary motor cortex between cortical thickness and R1/R2* changes. There also exists some minor regional changes. Detailed analysis will elucidate normal aging as well as iron-related pathology of the Alzheimer's disease.

Conclusion: In the 3 quantitative measurements, changes are large in the frontal lobe and less in the parietal and occipital lobes. Distribution of regional change amounts is basically similar with some differences. Multi-parametric quantitative analysis is expected to promote investigation of physiological and pathological changes in the human cortex.

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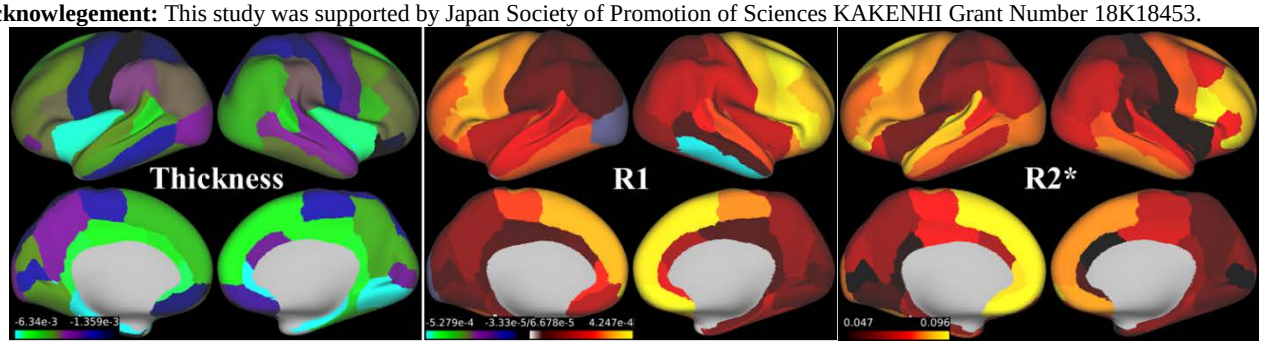

Figure 1. In all 3 quantitative values, lager changes were observed in the frontal lobe whereas lower in parieto-occipital lobes, and the superior temporal lobes in between them. Large difference was observed at the cingulate and primary motor cortex between cortical thickness and R1/R2* changes. R1 and R2* measurement reliability is low at insula and temporal & frontal bases, which are not discussed.

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