Sex difference and age dependence of the human brain structure delineated at the high magnetic field of 4.7T

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Introduction

Anatomical structure of the human brain is influenced by various environmental factors as well as genetic expressions. Those environmental factors must include nutritional, educational, and chemical ones. Volumetry and voxel based morphology of the brain achieved by high resolution MRI is one of the most powerful means to uncover the relation of those factors to the structure and function of the brain. Utilization of high magnetic field attains high sensitivity leading to the high spatial resolution, and high tissue contrast leading to the precise tissue discrimination. At high field, however, the contrast change due to prolonged T_1 and shortened T_2, or the nonuniformity in the image due to the dielectric B_1 inhomogeneity have to be overcome. In the present study we assessed the potential of the 3-dimensional MDEFT image for the volumetric analysis of the human brain, and sex difference and age dependence were considered on images collected from 75 healthy subjects at 4.7T.

Materials and Methods

Brain anatomical images were collected from 36 male (age range: 21-65 years, mean: 41.3), and 39 female (age range: 23-55 years, mean: 34.5) volunteer subjects. 3-dimensional MDEFT images in isotropic 1mm resolution were obtained on a 4.7T/92.5cm MRI system (Varian, Palo Alto) with a T_{MD} (T_1 contrast preparation period) of 2s and a flip angle of 13° which were optimized to 4.7T described elsewhere [1]. After the correction of nonuniform image intensity by 6th order Legendre polynomials in Brain Voyager software, the brain tissue segmentation was automatically performed based on SPM99 and Brain Extraction Tool (BET) in FSL software [2]. Total brain tissue volumes in grey matter (GM), white matter (WM), and cerebrospinal fluid (CSF) were calculated by summing the product of each tissue probability in the voxel and the voxel volume through the brain. Statistical analysis between male and female subjects was performed by Student's t-test, and the statistical significance of the correlation between tissue volume and age was tested by Pearson's correlation coefficient test.

Results and Discussion

Table 1 summarizes the mean volumes of total brain GM, WM, CSF, and the intracranial space as well as their normalized volumes (proportion of each tissue volume to the intracranial volume (ICV)) in male and female subjects. Since absolute volumes showed significant sex differences, they were separately analyzed, and only the normalized volumes were analyzed in males and females altogether. In the male brain total GM and WM volumes decreased with age, while CSF volume increased (Fig.1a). All these changes were significant. An annual GM decrease rate of 3.4ml was similar to the previously reported values [3]. In contrast to this, these volumes did not show significant age dependences in the female brain. The lack in the negative correlation between the female GM and age could partly be due to rather narrower age range in the female subjects and to the smaller total brain volume in younger females. The normalized GM showed an age dependent decrease in females as in males, yet its slope was milder than in males.

The age dependence of WM volume was still controversial in the previous studies. In a bulk cross sectional study with 769 normal Japanese the WM volume did not show the age dependent change [3], whereas in other 176 normal subject group WM increased up to the age of 43 years and then decreased [4]. No significant age dependence in our female WM was consistent with the former case, but the significant age dependent decrease in male WM with the latter case. In contrast to the negative correlation between male WM and age in the full age range, a positive dependence with age was exhibited in the regression analysis in WM data in the male subjects limited to younger than 45 years. Further to investigate this biphasic change in WM we performed quadratic regression analyses in males and females altogether on the tissue volumes normalized by ICV. Although the regression in the normalized GM was almost linear, the normalized WM and CSF gave moderate regression coefficients of 0.45 and 0.61 for the quadratic regression (Fig. 2). The normalized WM are highest at the age around 40 years, which is consistent with the quadratic age dependence proposed by Sowell et al [4]. It should be noted that the normalized CSF shows a steeper increase at around the same age as the maximum in WM. The age of 40 years might be the beginning of senescence.

Conclusions

We assessed the validity of the 3-dimensional MDEFT image at 4.7T for the volumetric analysis of the human brain. In the pilot study of 75 healthy subjects the sex difference and age dependent change in each brain tissue were demonstrated.

References

[1] N.Takaya, H.Watanabe, F.Mitsumori: Int.Soc.Magn.Reson.Med., 12, 2339 (2004)., [2] N.Takaya et al.: ibid, 13, 1277 (2005). [3] Y.Taki et al.: Neurobio.Aging, 25, 455-463 (2004). [4] E.R.Sowell et al.: Nature neurosci., 6, 309-315 (2003).

	male	female
GM (ml)	700 ± 65	630 ± 48
WM (ml)	506 ± 63	469 ± 48
CSF (ml)	198 ± 32	157 ± 24
ICV (ml)	1567 ± 117	1391 ± 97
GM/ICV (%)	44.7 ± 2.1	45.3 ± 1.5
WM/ICV (%)	32.3 ± 2.5	33.7 ± 2.0
CSF/ICV (%)	12.7 ± 2.1	11.3 ± 1.5

Table1. Segmented tissue volumes (mean±SD) and their normalized values by the intracranial volume (ICV) in male (n=36) and female (n=39) brains.

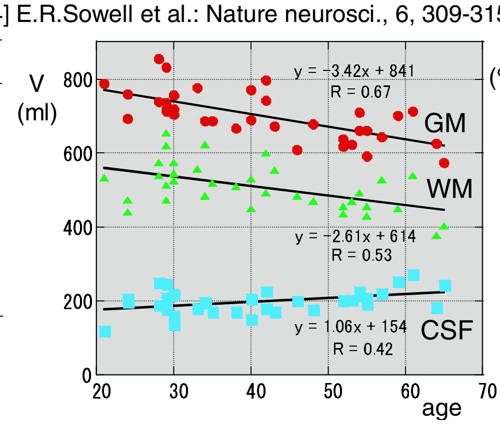

Fig.1. Age dependent changes in total GM, WM, and CSF volumes in the male brain.

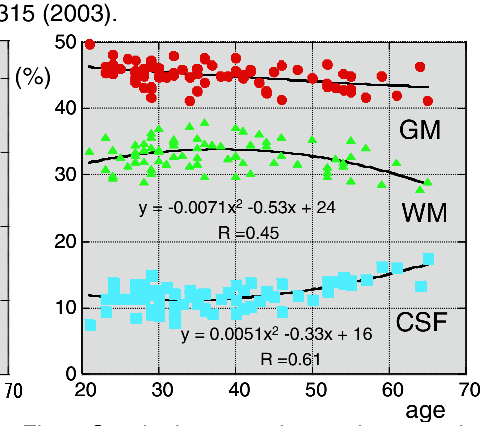

Fig.2. Quadratic regression analyses on the normalized brain tissues in all the subjects.