Age Dependence of Transverse Relaxation at 3.0 T in Normal Human Brain

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Introduction

The age dependence of transverse relaxation rate R_2 ($1/T_2$) in a specific anatomic structure in the normal human brain is an important baseline information for clinical applications of T_2-weighted imaging and quantitative parametric mapping. Using high-resolution R_2 mapping, we systemically characterized anatomical distribution of the R_2 variability with age in the human brain at 3.0 T.

Methods

Human Subjects

Thirty-seven healthy normal volunteers (20 males and 17 females, 24.1 ± 10.9 years of age, range 9 to 50 years) participated in the study. No significant age distribution difference between the two gender groups (p = .59). All subjects and parents of the subjects under 18 years old gave informed written consent prior to participation.

MRI protocol

A fast spin-echo sequence was used to scan the whole brain on a Bruker MedSpec S300 3.0 T system with a TEM head coil for reception. Then the field was manually shimmed at the hippocampus level. A series of T_2-weighted images were obtained using a multi spin-echo sequence (TR / TE / FA = 4000 ms / 11.8 ms / 180º, bandwidth = 80 kHz, 9 echoes, 20 2.5-cm-thick axial slices with no gap between slices, FOV = 25 × 25 cm^2, matrix = 256 × 192) for R_2 measurement.

Data processing and analysis

R_2 maps were generated using linear regression with CCHIPS/Interactive Data Language [1]. For statistical analysis, the R_2 maps from all the subjects were normalized to the Montreal Neurological Institute brain template [2] using SPM2 [3]. The resultant resolution of the R_2 map was 1 × 1 × 2.5 mm^3. The correlation of R_2 with age was analyzed on all the subjects and within the two gender groups.

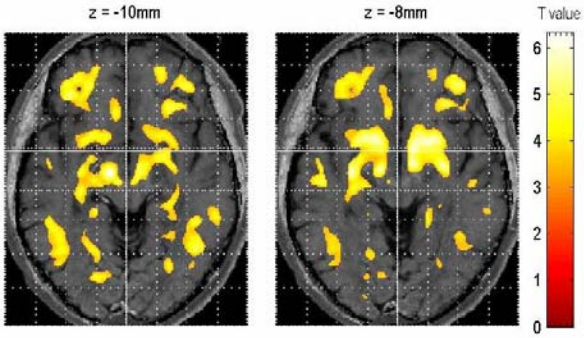

Figure 1. Positive correlation of R_2 with age in the basal ganglia, red nucleus and substantia nigra.

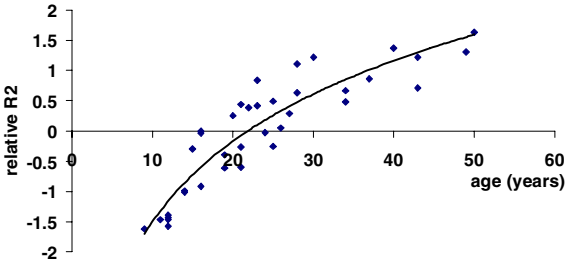

Figure 2. The age dependence of R_2 at left putamen from 37 healthy normal subjects ranging 9 – 50 years old (R^2 = .84).

Results

Voxel-based analysis showed an evident age dependence of R_2 in most deep brain gray matter structures within the studied age range. Figure 1 shows the positive correlation of R_2 with age in the basal ganglia, substantia nigra and red nucleus. Regression analyses revealed that an increase of R_2 follows a similar logarithmic trend in most of these structures, i.e., a rapid increase of R_2 from 9 to 20 yeas of age followed by a slower rate of increase from age 20 to 30 years. The rate of increase is further reduced after 30 years of age. Figure 2 shows R_2 at left putamen as a function of age. R_2 in most white matter areas appears relatively stable after age of 20. No significant difference was observed between the two gender groups (Ancova, T < 3.35) with age as a covariate.

	Amygdala	CN	Frt_WM	GP	Hipp	Ins_GM	M_F_GM	Pu	RN	SN	Temp_WM
Left	10.50/.28	12.39/.50	13.27/.35	16.59/.56	9.95/.21	10.36/.23	10.25/.25	13.91/.45	14.45/.68	15.57/.68	12.85/.46
Right	10.50/.27	12.45/.43	13.17/.29	16.57/.42	9.79/.18	10.27/.14	10.34/.19	13.99/.63	14.35/.60	15.21/.86	12.87/.31

Table 1. R_2 (mean/std, s^{-1}) of brain structures (age 30 to 50 years). CN: Caudate nucleus; Frt_WM: frontal lobe white matter; GP: Globus pallidus; Hipp: head of hippocampus; Ins_GM: insular cortex; M_F_GM: middle frontal lobe cortex; Pu: putamen; RN: red nucleus; SN: substantia nigra; Temp_WM: temporal lobe white matter.

Table 1 shows the heterogeneity of R_2 distribution in the brain (age 30 to 50 years). No lateralization is observed (paired t-test, p > .10).

Conclusion

The age dependence of R_2 in the brain exhibited a complex distribution with respect to brain anatomy. The brain areas demonstrating strong age dependence were those known having high iron concentration. The age regression curve followed an intriguing behavior strikingly similar to those of tissue iron concentration obtained by a postmortem study [4]. This indicates that tissue iron plays an important role in the changes of brain R_2 during normal development and aging and, conversely, R_2 mapping has the sensitivity in the detection of age-related iron changes in the brain in vivo. The normative data provided here are indispensable for clinical applications of quantitative R_2 parametric mapping.

References

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