R2* and Its Age Dependence in the Human Brain: A Normative Study

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Introduction

R_2* mapping (1/ T_2*) is under–utilized clinically because of substantial image artifacts in the heavily T_2*-weighted images produced by macroscopic magnetic field gradients in the head. Current R_2* imaging methods are limited by poor reproducibility and sensitivity. The mGESEPI technique is capable of removing the magnetic field inhomogeneity artifacts in T_2*-weighted images at high field [1]. Using this technique, we carried out a normative study to determine the variability and accuracy of the R_2* mapping method, which is essential for its clinical applications.

Methods

MRI protocol

R_2* maps were obtained from 28 normal subjects with an age range of 12 – 34 years old (average age 22.0 years, 18 males, 10 females, all right handed) using mGESEPI on a Bruker MedSpec S300 3.0 T system with a TEM head coil for RF transmission and reception. All T_2*-weighted images were acquired with TR = 360 ms, TE = 8 ms, number of echoes = 12, echo spacing = 4.23 ms, bandwidth = 100 kHz, FOV = 25 × 25 × 1 cm^3, matrix = 256 × 192 × 16, five 10-mm-thick axial slabs, no gap between slabs. In addition, R_2 measurement was conducted with a multi-echo SE sequence (TR / TE = 4000 ms / 11.8 ms, 9 echoes in an echo train, FOV = 25 × 25 cm^2, matrix = 256 × 192, twenty 2.5-mm-thick axial slices, no gap between slices). Test-and-retest was conducted on five normal male subjects (average age 29.0 years). R_2* measurements were carried out twice with mGESEPI before and after repositioning each subject in the same 3.0 T system.

Data processing and analysis

The mGESEPI data were reconstructed to twenty 2.5-mm-thick axial slices using a user-developed software based on Interactive Data Language. The R_2* maps were calculated on a pixel by pixel basis using linear regression. For statistical analysis, the R_2* parametric 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* parameter map was 1 × 1 × 2.5 mm^3.

Results and Conclusion

Figure 1 shows R_2* and R_2 maps form the same subject group. The R_2* distribution in human brain exhibits a greater heterogeneity. The known iron-rich brain regions are clearly delineated by a sharp contrast in the R_2* maps. While no lateralization is observed, R_2* showed significant differences among all known iron-rich brain structures, i.e. globus pallidus, putamen, red nucleus, substantia nigra, and caudate nucleus (two-sample two-tailed *t*-test, $p < 0.01$), indicating high sensitivity of R_2* mapping.

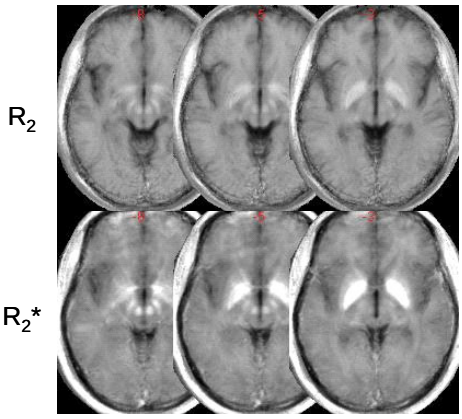

Figure 1. Average R_2 and R_2* maps from seven 25 – 28 years old normal subjects.

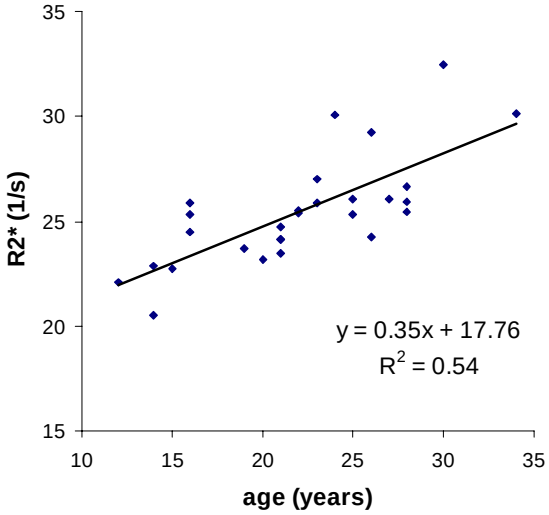

Figure 2. The age dependence of R_2* at right substantia nigra from 28 subjects ranging 12 – 34 years old.

A paired *t*-test did not show significant difference between the R_2* values from the test-retest scans ($p > 0.20$). With the subject group studied, R_2* reveals an evident age dependence. Figure 2 shows the average R_2* in the right substantia nigra of the 28 subjects as a function of age. R_2* values of other iron-rich brain structures exhibit similar trends with age. This positive correlation between R_2* and age is likely to associate with iron deposition in the brain. Iron in the brain is known to change with age with the most active period before 30 year of age [4]. To establish a comprehensive baseline, further investigations are needed to evaluate R_2* beyond the age range in the present study. Our data presented indicates that R_2* is sensitive in the detection of age-related changes and disorders in the brain.

In summary, our R_2* mapping technique is reliable and sensitive, allowing for detection of the age dependence of R_2* relaxation in normal human brain. The normative data provided here are necessary for clinical applications with R_2* imaging and quantitative parametric mapping.

References

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Acknowledgement

This research was supported by NIH (RO1 EB00454-01A1).