

Assessment of temperature induced changes of T₁ and T₂ relaxation times in the human brain

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Target Audience

Basic scientists with interest in relaxometry and scientists with interest in post-mortem MRI.

Purpose

As predicted by relaxation theory, the relaxation times of most tissues are expected to show a strong dependency on temperature. The dependency on temperature is caused by the rotational and translational motion of the water protons which affects their corresponding correlation times.¹ The exact knowledge of the temperature coefficient is important when translating findings from post-mortem MRI or when using MRI for thermometry such as during hypothermia or cryotherapy.² While the temperature dependency of T₁ has been assessed for the corticospinal fluid (CSF), it remains largely unknown for human brain tissue.³ Additionally, it remains unclear whether different brain structures exhibit different temperature coefficients. Given that formalin fixation alters the relaxation properties, conclusions about temperature dependency of relaxation rates can be hardly drawn from fixed tissue. The purpose of this work therefore was to investigate the exact temperature dependence of the T₁ and T₂ relaxation times in different brain structures. To reduce confounding impacts of autolysis and formalin-fixation, fresh and unfixed brain tissue were used.

Methods

Coronal brain slices (10 mm thick) from five deceased subjects (mean age = 70 years) with an autopsy requested by the local health authorities were included in this study. To increase the stiffness of the unfixed tissue the brain slices were embed in agar gel (14g/l), vacuum packed and mounted in a plastic sphere with a diameter of 180 mm. During MRI, at 3T the sealed plastic sphere was flushed with water at controlled temperatures between 4°C and 37°C. The temperature of the brain slice was measured continuously during the entire heating/cooling and scanning period. T₁ relaxation time was acquired using a turbo inversion recovery (TIR) sequence with TE/TR = 6.4/8000 ms, 4 inversion times (TI = 200, 800, 1600, 3200 ms), and an in-plane resolution of 0.8 mm². T₂ relaxation data was acquired using a turbo spin echo (TSE) sequence with TE = 10, 73, 115 ms, TR = 4000 ms, and an in-plane resolution of 0.8 mm². The T₁ and T₂ relaxation times were calculated for pre-specified ROIs assuming single-exponential relaxation. Temperature coefficients were obtained by linear regression analysis.

Results

We found a linear relationship between temperature and T₁ in the range of 4°C to 37°C. The strongest temperature dependency was found in the cortex (T₁ = 962 + 17.4 * T) and the lowest in white matter (T₁ = 695.8 + 3.4 * T). The basal ganglia (T₁ = 733.9 + 13.1 * T) showed a behavior similar to the cortex while the temperature coefficient of the thalamus (T₁ = 656.8 + 7.6 * T) was between cortex and white matter. No significant temperature dependency of T₂ was found in any regions.

Discussion

The temperature dependency of T₁ was in line with theoretical prediction but differed from values reported.² In contrast to the prediction by theory, the temperature dependency of the T₂ relaxation time is negligible small and seems to be masked out by other factors. Our results indicate that the temperature coefficient strongly depends on cellular structures which can restrict the molecular mobility. In contrast to gray matter, the myelinated fibers in white matter cause an anisotropic restriction which may, in addition to a lower water content, explain the significantly lower temperature coefficient.

Conclusion

While temperature does not affect the T₂ relaxation time in brain tissue, T₁ shows a linear dependency over a large range of temperatures. The temperature coefficient for T₁ mainly depends on cellular organization and therefore leads to substantial regional variations. The coefficients obtained in this study can serve as reference for thermometry or for correcting and comparing quantitative postmortem MRI to in-vivo results.

Reference

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3. Thelwall PE, Shepherd TM, et al. Effects of temperature and aldehyde fixation on tissue water diffusion properties, studied in an erythrocyte ghost tissue model. *Magn Reson Med.*;56(2):282–9.

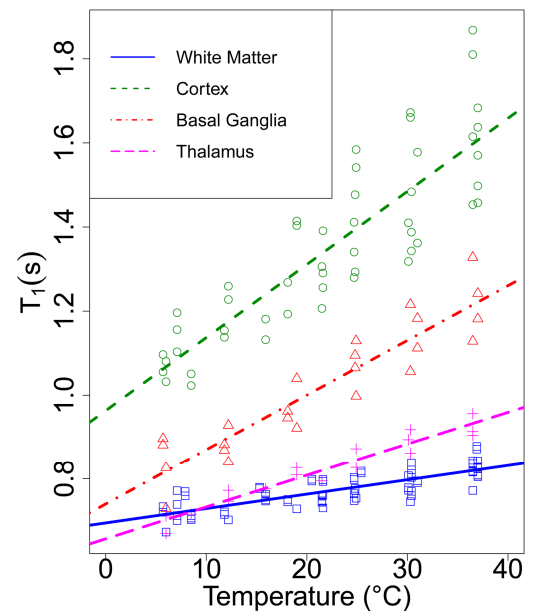


Figure 1 Temperature dependency of the T₁ relaxation time in white matter, cortex, basal ganglia and thalamus.