

T_{1ρ} Changes in the Human Brain during Respiratory Acidosis and Alkalosis

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Introduction

Brain pH changes have been shown useful in the assessment of tumors and stroke. In addition, disrupting the ASIC1a gene or blocking its activity have been shown to produce profound phenotypic effects in mice; including markedly attenuated anxiety, depression-related behaviors, prevention of neuronal loss in multiple sclerosis model, reduced neuronal injury in ischemia, and altered seizure severity. The ability to image pH dynamics holds great potential for assessing a variety of psychiatric and neurological disorders that are characterized by pH alteration. This study aimed to evaluate the utility of T_{1ρ} MR imaging as a method to measure pH dynamics. The sensitivity of T_{1ρ} to pH changes was evaluated in the in vivo human brain in respiratory acidosis and alkalosis.

Methods

MR images of the brain were obtained on a 3.0T Siemens Trio scanner (Siemens Medical Solutions, Erlangen, Germany) using a standard head coil. T_{1ρ} weighted images were acquired using a turbo spin-echo (TSE) sequence with a spin-locking preparation pulse which created a B₁ field of 500Hz. Imaging parameters were TR=3000ms, TE=12ms, field of view=240x240mm, imaging matrix size=128x64, bandwidth=130Hz/pixel and slice thickness=3cm. T_{1ρ} maps were generated from four T_{1ρ}-weighted images that were obtained by varying spin-locking times of 20, 40, 60 and 80ms. To evaluate the use of T_{1ρ} to detect changes in human brain pH, T_{1ρ} images were obtained from a subject under three conditions: 1) breathing 5% CO₂, 2) breathing room air, and 3) hyperventilating room air (30 breaths /minute). A least squares fitting algorithm was used to generate T_{1ρ} maps on a per voxel basis. The signal intensity (S) from the spin-lock sequence can be approximated by: $S = S_0 e^{-TSL/T_{1\rho}}$, where S₀ is the signal intensity produced when no spin-lock pulse is applied and TSL is the duration of spin-lock encoding.

Results

Fig. 1 (a) shows T_{1ρ} weighted images obtained with different spin-lock times (TSL=20, 40, 60 and 80ms). Fig. 1 (b) shows T_{1ρ} maps of the human brain varied with end-tidal CO₂ concentration (EtCO₂) during the 5% CO₂, room air, and hyperventilation conditions. The intensity maps represent T_{1ρ} times ranging between 50ms (basic) to 100ms (acidic). During CO₂ inhalation the widespread increase in T_{1ρ} times are consistent with the expected acidosis as compared to the baseline room air condition. Whereas the reduced T_{1ρ} times during hyperventilation are consistent with the expected alkalosis. The pH dependence of T_{1ρ} in brain tissue is clearly seen in the Fig 2. The increase of T_{1ρ} values were observed for all three tissues: white matter (WM), gray matter (GM), and putamen. During hyperventilating T_{1ρ} was decreased by 8% in GM and putamen, and 7% in WM compared to the baseline room air. However, T_{1ρ} during 5% CO₂ inhalation was increased by 13% in GM, 6% in putamen, and 9% in WM.

Discussion and Conclusions

This human study shows that the T_{1ρ} imaging is sensitive to pH changes using a set of respiratory challenges. The respiratory alkalosis by hyperventilating showed decreased T_{1ρ} times compared to the baseline. In contrast, the respiratory acidosis by breathing 5% CO₂ showed increase T_{1ρ} times. This result agreed well with our previous phantom and mouse study which show negative relationship between T_{1ρ} and pH [1]. The ability to non-invasively measure pH dynamics in the human brain using T_{1ρ} MRI could offer a novel, more direct approach to map brain function as well as detect human neurological disease and assess treatment response.

Reference

[1] Heo et al.; Measuring T_{1ρ} changes related to alkalosis and acidosis. Proceedings of the 18th Annual Meeting of ISMRM; Stockholm. 2010.

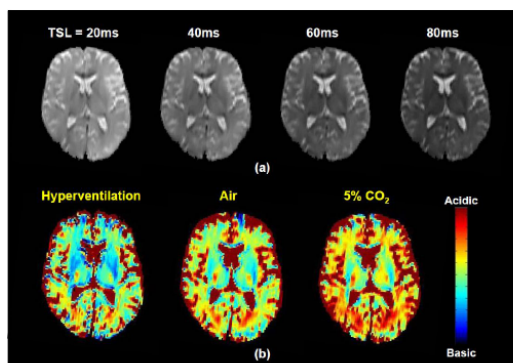


Fig. 1. T_{1ρ} weighted images (a) and T_{1ρ} maps during respiratory challenges

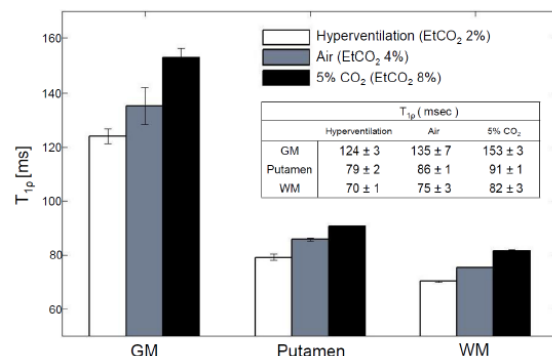


Fig. 2. T_{1ρ} values in four tissues with respiratory challenges