In vivo Relaxation Parameters of Oxygen-17 (^{17}O)

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INTRODUCTION

Cellular energy production is closely connected to the metabolization of oxygen (O_2) to water (oxidative phosphorylation). Direct ^{17}O-MRI can assess the *in vivo* concentration of $H_2{}^{17}O$ metabolized from inhaled ^{17}O gas. Thus, it measures the oxygen turnover providing functional tissue information [1]. However, the MR-sensitivity of the ^{17}O nucleus (I = 5/2) is poor because of the low gyromagnetic ratio ($\gamma_{17O} = \gamma_{1H}/7.4$) and the fast relaxation due to the quadrupolar coupling. Information on the relaxation parameters of the imaging object is therefore crucial for optimizing the imaging sequence in terms of signal-to-noise ratio (SNR) and the determination of *in vivo* $H_2{}^{17}O$ concentrations [2]. As the optimal SNR per unit acquisition time is proportional to $(T_2^*/T_1)^{1/2}$, both relaxation parameters, T_1 and T_2^*, are affecting the SNR. In this study we measured the *in vivo* ^{17}O relaxation times in the human brain at B_0 = 7 T to optimize imaging protocols for $CMRO_2$ (*cerebral metabolic rate of oxygen consumption*) measurements. Non-localized detection (T_1, T_2) was carried out in 10 healthy volunteers and 3D T_2^* determination and anatomical mapping to ^1H images was performed in one subject.

MATERIAL & METHODS

Measurements were carried out on a 7 Tesla whole-body MR-system (Magnetom 7T, Siemens, Erlangen, Germany). Direct ^{17}O-MRI of the natural abundance ^{17}O concentration in the human head was performed using a custom-built quadrature ^{17}O Tx/Rx head coil. Anatomical ^1H data was acquired in a separate measurement using a 24-channel Tx/Rx head coil (Nova Medical, Inc., Wilmington, USA) and a spoiled gradient echo sequence. A 3D radial ultrashort echo time sequence with adapted k-space sampling density was applied for ^{17}O imaging [3].

T_2^*-mapping: Data sets of 9 different echo times (0.65 ms – 8.00 ms) with a nominal spatial resolution of $(6\ mm)^3$ were acquired in a total acquisition time of 67:30 min (TR = 18 ms, readout time = 5.6 ms, pulse duration = 1 ms, projections = 25k, averages = 1). A flip angle of $\alpha = 65°$ was used to meet SAR requirements. A mono-exponential decay function was fitted to the data.

Non-localized meas.: Non-localized spin-echo and inversion recovery sequences were applied to determine global T_1, and T_2 values, respectively.

^{17}O-imaging: An SNR optimized *in vivo* imaging protocol was prepared from the relaxometry results and ^{17}O imaging of the human head was carried out. Natural abundance ^{17}O images with an isotropic nominal spatial resolution of $(5.5mm)^3$ were acquired in T_{AQ} = 9:54 min (TR = 11 ms, TE = 0.7 ms, readout time = 5.04 ms, $\alpha = 64°$, pulse duration = 1.2 ms, projections = 27k, averages = 2).

RESULTS AND DISCUSSION

T_2^* relaxation time maps of a central transversal and sagittal slice are displayed in Fig. 1. Image co-registration of anatomical ^1H and ^{17}O imaging data was applied for separating brain regions in the T_2^* analysis (Fig. 2). A region of interest analysis of the ^{17}O T_2^* maps showed: Gray/white matter $T_2^* = 2.02 \pm 0.17$ ms, CSF $T_2^* = 3.12 \pm 0.20$ ms, eyes $T_2^* = 3.68 \pm 0.15$ ms and cerebellum $T_2^* = 1.91 \pm 0.24$ ms.

Additionally, averaged non-localized relaxation times of $T_1 = 5.77 \pm 0.14$ ms and $T_2 = 2.71 \pm 0.14$ ms were found (n = 10). The average brain matter value of $T_2^* = 2.02$ ms was used to determine an optimum-SNR readout duration of $T_{RO} = 5.02$ ms when applying a Hamming filter to the images [4]. Natural abundance *in vivo* ^{17}O images acquired with an optimized protocol are shown in Fig. 3. An average SNR = 30 was determined for white/gray matter, SNR = 38 was found in fluid filled spaces (CSF, eyes).

CONCLUSION

In this study we investigated the *in vivo* relaxation parameters of ^{17}O in the human head at B_0 = 7 T. Optimum imaging parameters were determined from the data and applied in an SNR optimized ^{17}O-MR imaging protocol for $CMRO_2$ studies.

REFERENCES

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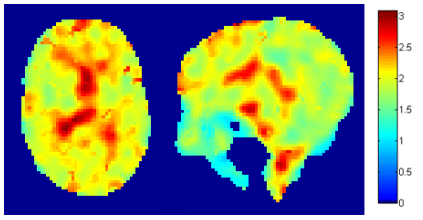

Fig.1: 3D mapping of the ^{17}O T_2^* [ms] relaxation times in the human brain acquired at B_0 = 7T. A representative transversal and sagittal slice are shown.

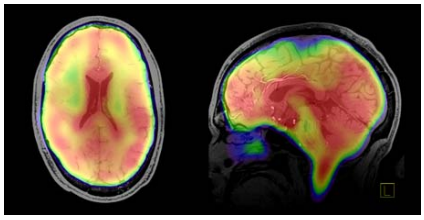

Fig.2: Image co-registration of nat. ab. ^{17}O data (color) to ^1H images (grayscale) for delineation of anatomical structures.

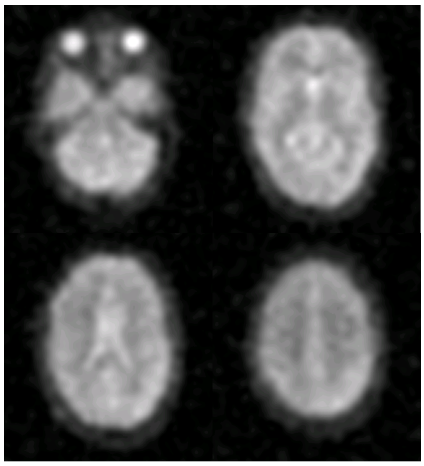

Fig.3: Natural abundance ^{17}O images of the human head with an isotropic spatial resolution of $(5.5mm)^3$ and SNR_{mean} = 32.