In Vivo ^{17}O-MRI at 3 Tesla using a TxRx Surface Coil

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Introduction: Oxygen-17 (^{17}O) MRI is a promising method to assess the metabolic turnover of oxygen *in vivo*. Oxygen consumption is an important parameter for the prognosis of cancer, Alzheimers and Parkinsons disease and normal aging. The low natural abundance (0.037%) and the short relaxation times of the $I = 5/2$ nucleus ^{17}O lead to very low MR signals. Direct ^{17}O-MRI has been carried out so far at 1.5T and at ultra-high fields [1, 2]. In this work a transmit / receive (TxRx) ^{17}O surface coil for 3 Tesla is presented to enable ^{17}O MRI studies at clinically available high field strengths.

Materials & Methods: A single-resonant, single-loop surface coil (Ø = 15 cm) was constructed from copper tubing (Ø = 5 mm). The coil was tuned to the Larmor frequency of ^{17}O at 3 Tesla (f = 16.7 MHz) and matched to 50 Ω. A TxRx-switch was built including a modified preamplifier from a 1.5 T MR system (Magnetom Vision, Siemens Healthcare, Erlangen, Germany) tuned to 16.7 MHz (Fig. 1).

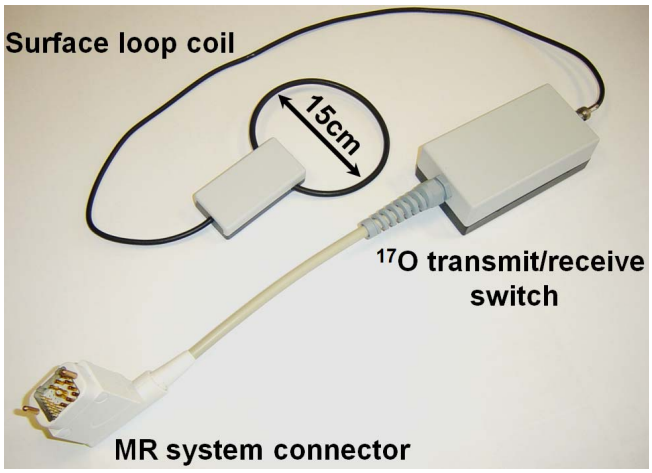

Figure 1: Complete setup of the TxRx switch and surface coil for ^{17}O imaging at 3 Tesla.

Phantom measurements were performed on a cylindrical resolution phantom (Ø = 18.5 cm, height = 3 cm) at a 3 Tesla MR System (Magnetom TIM Trio, Siemens). The phantom was filled with an aqueous solution with ^{17}O in natural abundance. Imaging was performed using an adapted 2D FLASH sequence with the following parameters: TE = 5 ms, TR = 15 ms, TA = 16 min, α = 20°, 1000 averages, SL: 30 mm, BW: 60 Hz/px, FoV: 320 mm², Matrix: 64×64, Res: 5×5×30 mm³. For comparison ^{1}H images were acquired with a flexible surface coil and a 2D FLASH sequence: TE = 5 ms, TR = 20 ms, α = 15°, SL: 15 mm, BW: 80 Hz/px, FoV: 320 mm², Matrix: 512×512, Res: 0.64×0.64×15 mm³.

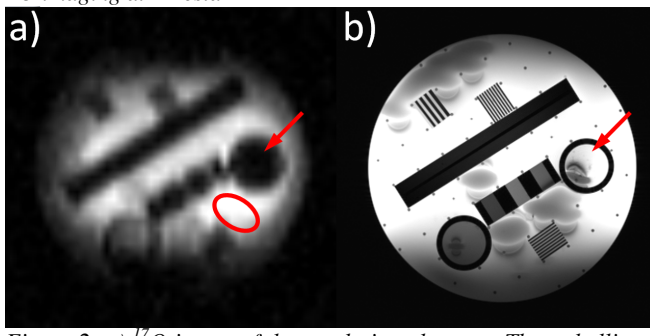

Figure 2: a) ^{17}O image of the resolution phantom. The red ellipse depicts the ROI for SNR calculation b) Corresponding ^{1}H image. The oil-containing vessel (red arrow) is only visible in the ^{1}H image as it contains no oxygen.

Initial *in vivo* images were acquired in a healthy male (29y) volunteer with the ^{17}O coil placed near the visual cortex. The following imaging parameters were used: TE = 4 ms, TR = 15 ms, TA = 5 min, α = 20°, 600 averages, SL: 25 mm, BW: 100 Hz/px, FoV: 400 mm², Matrix: 32×32, Res: 12.5×12.5×25 mm³. High-resolution T1w ^{1}H imaging was conducted for comparison using the system's 8-channel head coil and an MP-RAGE sequence with the following parameters: TE = 3 ms, TR = 2.3 s, TI = 1.1 s, TA = 7 min, α = 12°, SL: 1 mm, BW: 130 Hz/px, FoV: 244×270 mm², Matrix: 256×232.

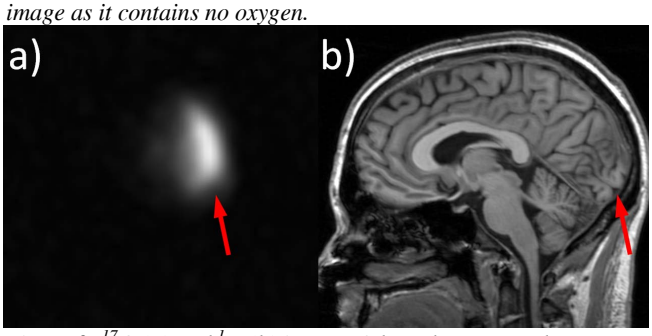

Figure 3: ^{17}O (a) and ^{1}H (b) image of the volunteer. Red arrows indicate corresponding anatomical regions.

Results: Figure 2 shows in vitro results of the ^{17}O imaging compared to the corresponding ^{1}H image. The SNR of the ^{17}O images amounts to 44 (according to NEMA [3]). Note, that the oil-containing vessel (arrow) is invisible in the ^{17}O images. Figure 3 shows the preliminary *in vivo* ^{17}O images of the visual cortex compared to a ^{1}H image of the same position – even though anatomical substructures cannot be resolved, the general shape of the brain is clearly visible (cf. overlay in Fig. 4). The ^{17}O SNR close to the coil was found to be 50.

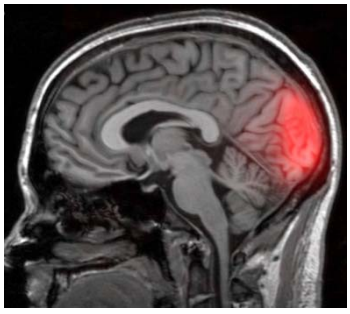

Figure 4: Manual overlay of the ^{17}O (red) onto the corresponding ^{1}H image.

Discussion & Conclusion: In this work ^{17}O MR images were acquired at a clinical 3 Tesla MR system. These preliminary results show that with an SNR of 45 *in vitro* and 50 *in vivo,* direct ^{17}O MRI at 3 Tesla can be accomplished in clinically acceptable acquisition times (15 min and less). To increase both the ^{17}O signal and the spatial resolution, sequences with ultra-short echo times (UTE) will be used in the future, and dedicated volumetric TxRx coils will be designed for whole-brain imaging.

References:

[1] D Fiat et al. Neurol Res (2004), 26: 803-8, [2] SH Hoffmann et al. Magn Reson Imaging (2011), 66: 1109-15, [3] NEMA Standards Publication (2001) MS 1-2001