A novel double tuned 4T $^1H/^{17}O$ head volume coil

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Target Audience: This work is of interest to researchers studying the cerebral metabolic rate of oxygen ($CMRO_2$) under normal conditions.

Purpose: Recently, the $CMRO_2$ measurement based on high-field ^{17}O MRSI, combined with the brief inhalation of ^{17}O-isotope-enriched oxygen gas, has been introduced. The reliability and applicability of this approach has been rigorously validated in animal models [1]. However, these works were performed on surface coils. In this work, we developed a double tuned $^1H/^{17}O$ head volume coil to advance this technique to the entire brain. Specifically, we will compare the performance of a double tuned ($^1H/^{17}O$) TEM and a 4-channel phased array coil.

Methods: A double tuned $^1H/^{17}O$ head volume coil consisted of two nested components (Fig. 1) was implemented. A 16-element quadrature ^1H TEM volume coil was used to acquire data at ^1H frequency. For convenience the volume coil was split into two portions using technology described previously [2]. The TEM coil was driven in quadrature using capacitive matching and a two-port drive [2,3]. The smaller ^{17}O transceiver phased array circumscribing the head was located inside of the TEM coil (Fig 1, right). To provide better fit, the array holder was also split into two portions with the position of the top portion being vertically adjustable; changing the array height from 21 to 23 cm. The array consisted of four 12 x 9.5 cm surface coils constructed using 6.4 mm copper tape. After inductive decoupling, the isolation between all four surface coils was better than -18 dB when loaded with either a head or a head-mimicking 2.0 L (50 mM NaCl) spherical phantom. A second coil was used for comparison with a conventional 16-element quadrature TEM design for both ^1H and ^{17}O channel.

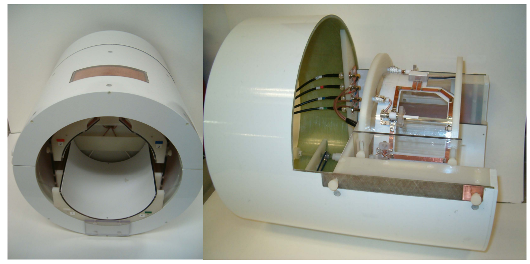

Figure 1

All MR studies were performed on a Varian INOVA 4T MRI system. Six healthy human subjects were scanned using both coils. Seven in vitro ^{17}O phantom datasets were acquired using the same parameters. All patients had a 3D ^1H MDEFT anatomical image acquired and a one-pulse 3D ^{17}O MRSI acquired using a three-dimensional weighted spherical sampling scheme (TR= 100 ms; NT=1; 90° hard pulse =400µs and 750 µs for phased array and TEM coil, respectively). MRSI was collected in three different methods: 1) phased array coil in phased array mode, 2) phased array coil in combined mode, and 3) TEM coil in quadrature mode. Each MRSI data matrix was 13 x 13 x 13 with a 24 x 24 cm^2 field of view. Each FID had 512 complex points and a 10 kHz spectral width. All of the data analysis was performed in MATLAB using in-house software. The 3D MRSI matrix was zero-padded to 16 x 16 x 16 prior to processing. After a point spread function correction, the nominal voxel resolution was approximately 12 ml. ^{17}O maps were generated using the 1D-3D FT method discussed by Lee et al. [4].

Results: Figure 2 shows images obtained from a volunteer using the above mentioned approaches – phased array, combined, and quadrature mode from top to bottom, respectively. We have demonstrated that whole brain ^{17}O MRSI is feasible at 4T and the total acquisition can be 3 minutes or less.

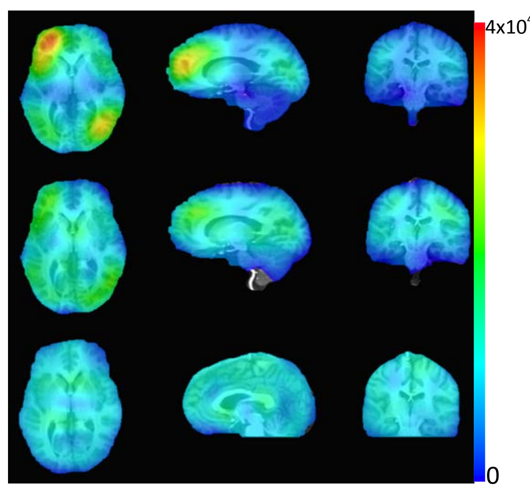

Figure 2

Discussion: Due to a short T_1 for ^{17}O, a whole brain 3D MRSI can be done in a few minutes. The data showed that the signal-to-noise (SNR) of the center of the images of all three approaches were comparable, while the SNR of the periphery was highest in the phased array mode and lowest in the quadrature mode. The images obtained by the TEM coil have a more uniform B_1 field but possess the lowest overall SNR. On average, the SNR from the phased array coil was about 2.4 times higher than the TEM coil. Results from phantom data confirmed this finding (data not shown).

Conclusion: This finding confirms that the advantage of a phased array coil is evident for both RF excitation efficiency and SNR. The B_1 inhomogeneity of phased array coils is well-known and can be a concern. However, this can be minimized by measuring the B_1 map and/or post-processing approaches.

References: [1]. Zhu et al, NMR in Biomedicine 2005;18:83-103. [2] Vaughan et al., Magn. Reson. Med. 32 (1994) 206-218. [3]. Avdievich et al., J. Magn. Res. 187 (2007): 234-241. [4]. Lee et al., Magn. Reson. Med. 68 (2012) 363-8.