A PET Compatible $^{17}O/^{1}H$ Coil for Simultaneous Multinuclear PET/MR

Seena Dehkharghani, Karthik Lakshmanan, Prodromos Parasoglou, Guillaume Madelin, and Ryan Brown
Department of Radiology, New York University Langone Health, New York, NY, USA

Audience: Physicians and engineers interested in studying brain oximetry and metabolic function using MR/PET.

Purpose: Brain homeostasis depends critically upon the steady nutritive flow of oxygenated blood, hinging on the immense energetic advantage of oxidative phosphorylation to sustain the neurovascular unit at rest and during explicit activation. Seminal paradigms describing hemodynamic compromise amid declining perfusion pressures were expounded through use of ^{15}O PET, emphasizing a tenuous state of *misery perfusion* marked by impaired oxygen metabolism and conferring elevated near-term stroke risk [1-3]. Technical obstacles associated with extremely short-lived ^{15}O have motivated the development of ^{17}O-MRI as an alternative means to assess oxygen metabolism. However, its low natural abundance (0.037%) commonly requires ultrahigh field (7T) conditions coupled to fractionally enriched ^{17}O gas inhalation [4-7]. With the preceding in mind we developed a PET-compatible dual-tuned $^{17}O/^{1}H$ coil array, which combined with a time efficient pulse sequence allows high sensitivity brain oximetry at natural abundance along with the unique opportunity to simultaneously detect PET tracers for complementary insight on brain metabolism on a clinical 3T PET/MR system.

Methods: We developed a dual-nuclei radio frequency coil array for ^{17}O and ^{1}H-MRI that consists of two radially interleaved four (^{17}O, 16.7MHz) and eight (^{1}H, 123.2MHz) channel arrays (Fig. 1). We minimized PET attenuation by consolidating the coil into a two "layer" degenerate-mode birdcage structure (one transmit/receive ^{17}O layer and one receive-only ^{1}H layer), moving MRI interface components and capacitors outside the PET FOV, and enclosing the device in a 3D printed (Fortus 360, Stratasys, Eden Prairie, MN) stealth polycarbonate shell. The MRI interface was set up to drive the ^{17}O array in the circularly-polarized mode for uniform spin excitation, while signal detection was performed in phased-array mode for high SNR.

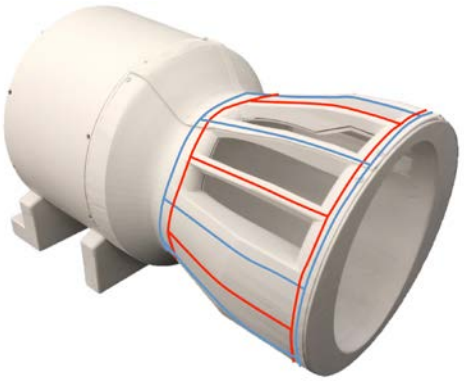

Figure 1. Coil photo with overlaid ^{17}O (blue, 4 channels) and ^{1}H (red, 8 channels) elements. The stealth housing structure and remote MRI interface minimize PET attenuation. A positioning mechanism at the service end locks the coil to the MR/PET patient bed to ensure accurate PET attenuation correction.

Pulse sequence: Data were acquired on a whole body 3T scanner with multi-nuclear capability (Prisma, Siemens Healthineers, Erlangen, Germany) using the Fermat Looped Orthogonally Encoded Trajectory (FLORET) sequence [8] with the following parameters: TE 0.2 ms, TR 50 ms, FOV 512 mm, matrix size 64×64×64, resolution 8 mm isotropic, 3 hubs at 45°, 140 interleaves/hub, FA 90°, pulse duration 0.5 ms, 50 averages, readout time 10.3 ms, TA 17:30 min. Images were reconstructed using standard 3D regridding after sampling density compensation [9] and Hamming filtering of the raw data. The full width at half maximum of the point spread function (including Hamming filter) is 1.9 pixel, resulting in 15.2 mm real resolution.

Results and Discussion: Derangements in oxygen metabolism are fundamental to many pathologic processes. Herein we report development and experimentation of a custom, dual-tuned multinuclear $^{17}O/^{1}H$ coil designed for simultaneous PET/MR on a routine clinical 3T system. Successful detection of ^{17}O signal in the healthy human brain (Fig. 2) confirms earlier studies [10] on the feasibility of direct, non-invasive endogenous MR oximetry at natural abundance and empirical characterization of oxygen metabolism. In addition, our PET-compatible architecture will allow simultaneous ^{17}O-MRI functional tissue characterization and PET neuroimaging to study different aspects of brain energy metabolism.

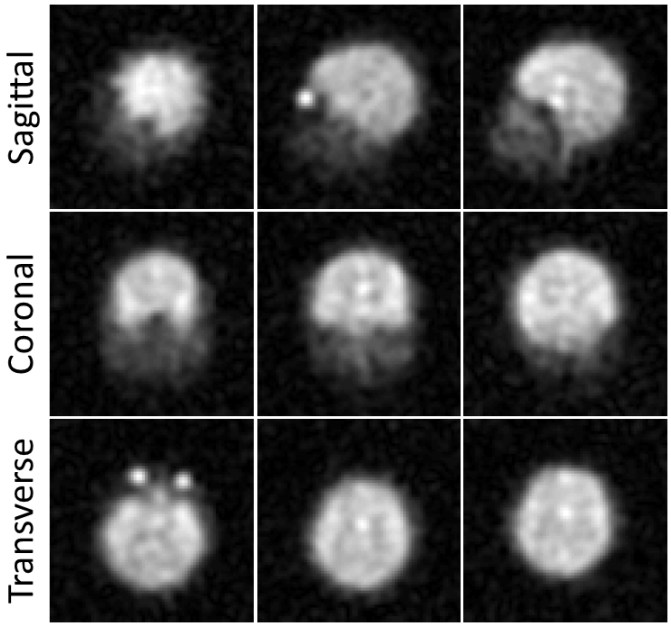

Figure 2. Examples of ^{17}O images in brain at 3T (8 mm isotropic resolution, 17:30 min acquisition).

References: [**1**] C. P. Derdeyn, et al. Brain 2002. [**2**] R. L. Grubb, Jr., et al. J Neurosurg 2013. [**3**] W. J. Powers. Ann Neurol 1991. [**4**] X. H. Zhu and W. Chen. Prog NMR Spectrosc, 2011.[**5**] D. Kurzhunov, et al. Magn Reson Med 2017. [**6**] D. Kurzhunov, et al. Neuroimage 2017. [**7**] S. H. Hoffmann, et al. Magn Reson Med 2011.[**8**] J. G. Pipe, et al. Magn Reson Med 2011. [**9**] J. G. Pipe and P. Menon. Magn Reson Med 1999. [**10**] R. Borowiak, et al. MAGMA 2014.