Translational study of MOBILE (Mapping of Oxygen By Imaging Lipids relaxation Enhancement) on a clinical 3T scanner: initial study in comparison with R2* and R1 H2O in the brain of healthy volunteers.

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Purpose and objectives: Variations in T_1 (longitudinal relaxation rate) and T_2* (transversal relaxation rate) are potentially valuable magnetic resonance imaging (MRI) tools to quantify changes in tissue oxygenation. T_2* is sensitive to the relative Hb/HbO_2 ratio in vessels (1), while T_1 change is sensitive to dissolved oxygen which acts as a T_1-shortening paramagnetic contrast agent (2). Recently, changes in tumor oxygen concentrations have been shown to produce changes in relaxation rate R_1 (=1/T_1) of water (3) and studies have demonstrated that oxygen-enhanced MRI produces measurable signal changes in normal tissues in patients and is feasible on conventional clinical scanners (4). The purpose of the current work was to translate the MOBILE technique, a method developed to map variations in oxygenation based on the changes in the relaxation properties of the tissue lipids by exploiting the higher solubility property of oxygen in lipids than in water (5), on a 3T clinical MR scanner. MOBILE consists in the selective measurement of the lipids relaxation rate with water suppression. In order to validate the technique, we compared the sensitivity of MOBILE in the brain of healthy volunteers (n=4) with changes in R_2* and R_1 of water with respect to an hyperoxic breathing challenge.

Material and Methods:

Protocol: The translational properties of the MOBILE sequence were evaluated by: (i) implementing the sequence on a clinical 3T Philips MR system and verification of appropriate water suppression and sampling of T_1 of lipids in vitro on phantoms, and (ii): imaging brain of volunteers (n=4) and assessing R_1 H_20, R_1 Lipids, and R_2* under air and 100% oxygen breathing conditions.

MR methods: MR imaging was performed at 3.0T (Achieva; Philips Medical System) using a transmit/receive head coil. 3 different imaging sequences were used during baseline acquisition (air breathing) and 5 minutes after oxygen breathing (15L/min):

- For T_1 measurement: a Look Locker sequence (T_1 TFE, T_1 Turbo Field Echo sequence) was applied during 24 seconds with TR/TE/NA/Flip angle/tfe= 3.467ms/1.45 ms/1/5°/10. 140 images with 20 mm of thickness and 80x80 pixels were obtained.
- For MOBILE measurements, the same sequence was used and a 90° SPIR pulse was added (Spectral saturation by Inversion recovery) to spoil water with a BW of 300Hz centered on the water peak. The acquisition lasted 4 minutes and 117 images with 20 mm of thickness and 80x80 pixels were obtained.
- For T_2* measurements, a Multi fast field echo mFFE sequence was performed with 15 echoes with a total acquisition time of 40 seconds (a verifier). A 320x320 pixels matrix was obtained with TR/flip angle/slice thickness=250ms/ 18° /4 mm.

Results:

We observed that regions of interest (ROIs) corresponding to a negative change in R_2* (corresponding to positive response to oxygen breathing) were systematically correlated with a positive change in R_1 of lipids, that was either similar or superior in terms of sensitivity. Oxygen induced changes in R_1 H_2O in matched ROIs either showed a small positive response (<5%) or a negative response.

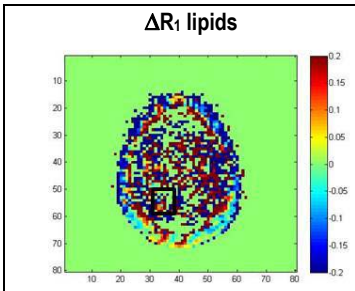

Fig.1. map of variation in R_1 Lipids during oxygen breathing

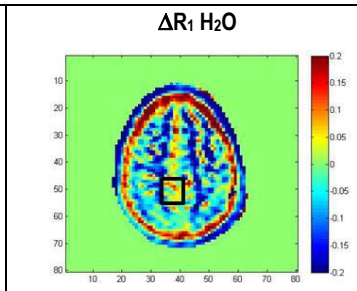

Fig.2. map of variation in R_1 water during oxygen breathing

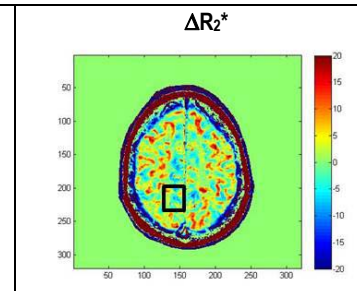

Fig.3. map of variation in R_2* Lipids during oxygen breathing

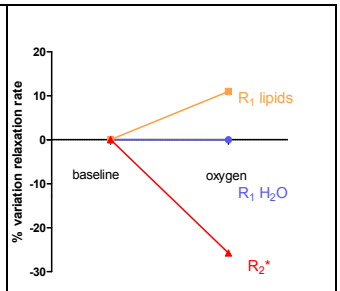

Fig.4. mean change in relaxation rates in the □ ROI

Discussion:

This work establishes the translational properties of MOBILE in the clinical setting. By comparing with well-known T2* (fMRI) and T1 methods, our data suggest that MOBILE presents good sensitivity to changes in pO2. The lack of concordance between the 3 measurements in some matched regions of interest also suggest that the methods might be complementary by providing us with oxygenation measurements from different compartments (i.e. R_2* is likely to be more representative of the blood oxygenation status whereas R1 H20 or R1 lipids is likely to be more representative of tissue oxygenation).

References:

(1) Baudelet et al, Magn Reson Med 2002, 48, 980-986 (2) O'Connor et al, Int J Radiat Oncol Biol Phys 2009, 75, 1209-1215 (3) Magat J. et al, Proc. Intl. Soc. Mag. Reson. Med. 19 (2011) 553.