Imaging the healthy human brain with hyperpolarized ^{13}C MRI.

METHODS

Four healthy volunteers were imaged at 3T (MR750, GE Healthcare, WI) in a dual tuned ^{1}H/^{13}C head coil (Rapid, Germany). T_1 weighted ^{1}H images (3D-inversion-prepared, repetition time (TR) = 8.1ms, echo time (TE) = 3.1ms, resolution = 1x1x2mm^3, flip angle (FA) = 12˚, FOV = 240mm) were acquired and subsequent ^{13}C imaging was performed after injection of approximately 250 mM hyperpolarized [1-^{13}C]pyruvate using a GE SPINlab (0.4ml/kg; injection rate 5ml/s). All analysis and image reconstruction was performed in Matlab 2017a (The Mathworks, MA). White and gray matter masks were produced from segmentation of T_1 images (SPM 8, UCL, London), and were applied to the ^{13}C images (figure 1A). Summed images and spectra were produced from each dynamic time course.

RESULTS

Dynamic images showed hyperpolarized [1-^{13}C]pyruvate and [1-^{13}C]lactate in the brain (figure 2A-B). Time averaged pyruvate and lactate maps superimposed on the proton images are shown in figure 3. A time series of spectra is shown in figure 2C. The average signal within gray and white matter is shown in figure 1B: a relatively higher pyruvate signal was observed in gray matter and the peak pyruvate signal was at 8 s in white matter and 10 s in gray matter. The peak lactate signal was at approximately 10 s in both regions. The ratio of lactate-to-pyruvate summed over the whole brain, as determined from both spectroscopy and imaging, was 0.2 ± 0.05 for all three volunteers.

DISCUSSION

These are the first images of hyperpolarized [1-^{13}C]pyruvate metabolism in the normal human brain. They suggest that pyruvate transport across the intact blood brain barrier (BBB) is sufficient rapidly to allow real time metabolism to be observed within the lifetime of hyperpolarized ^{13}C signal. Differential perfusion of white and gray matter was observed, with the white matter peak occurring ~2 s prior to that in gray matter (figure 1B). The higher gray matter pyruvate signal may reflect increased perfusion of this region (5) as a similar lactate signal was observed in both areas.

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Anti-clockwise from top: Figures 1, 2, 3.