

Carbon-13 Metabolic Imaging at 3T using Hyperpolarized ^{13}C -1-Pyruvate

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Introduction: The recent development of a method to retain dynamic nuclear polarization (DNP) in solution (Ardenkjaer-Larsen et al) has enabled a new field of MR Imaging and Spectroscopy. One of the most important developments is the ability to image endogenous substances (Golman et al) and to follow metabolic changes of a hyperpolarized agent. In this study we demonstrate anatomical differences in pyruvate metabolism by spectroscopic imaging of pyruvate and its metabolic products lactate, alanine and bicarbonate.

Methods: Hyperpolarized $^{13}\text{C}_1$ -pyruvate obtained by DNP (Ardenkjaer Larsen et al.) was dissolved and 6ml of the hyperpolarized solution was injected into the tail vein of an anesthetized 250g Sprague-Dawley rat within 60 seconds of dissolution. The rats were imaged in a custom built dual-tuned rat coil in a GE Signa Excite 3T clinical scanner. Reduced k-space 16×16 ^{13}C -MRSI images were acquired starting 15s after injection. A 4cm axial slice centered at the level of the kidneys was collected at a FOV 80mm x 80mm. TR was 80ms with a spectral width of 5000 Hz and 256 spectral points. Data were processed with 16Hz Gaussian spectral apodization, zero-filled to 512 points spectrally and 64×64 points spatially. Metabolite images are presented as magnitude color overlays on a gray-scale proton reference image. Regional spectra are the average of 4 voxels after the zero-filling interpolation.

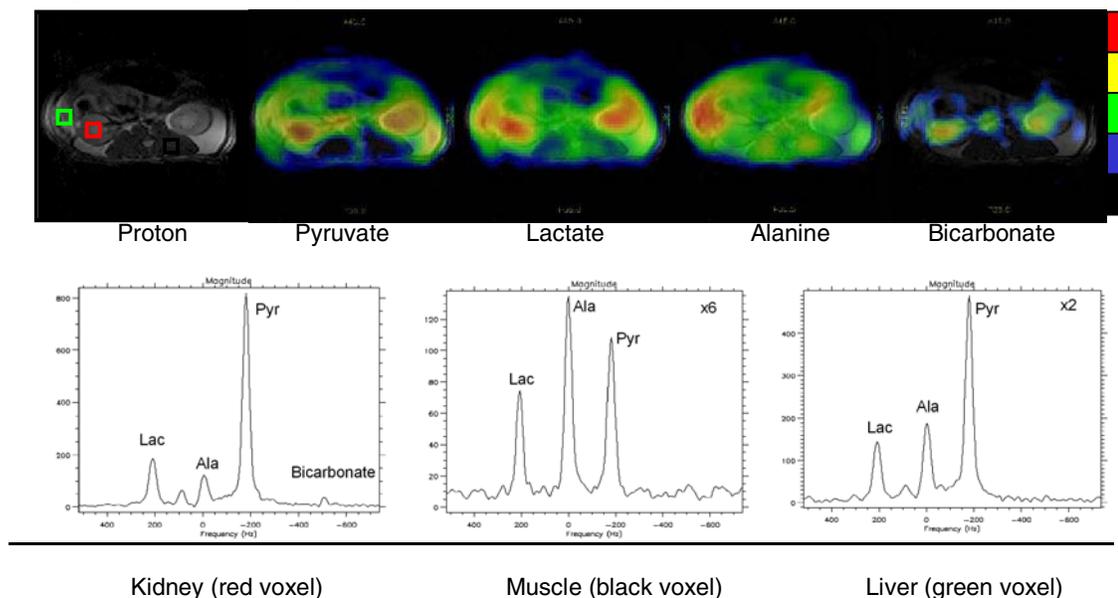


Figure 1. Metabolite maps and spectra from hyperpolarized ^{13}C MRSI of rat. High pyruvate, lactate and bicarbonate in kidney, low pyruvate and lactate in muscle and high alanine in liver, characteristic pattern observed in the both rats imaged. Although the current imaging method, a 16×16 MRSI, averages over a period of 30-47 seconds after injection, the relative patterns appear to be conserved. Spectra are from regions as indicated on the proton reference image.

Discussion: This study has demonstrated the feasibility of using hyperpolarized ^{13}C pyruvate in an in vivo experiment in a clinical setting on a commercial 3T MR scanner. This study demonstrates the potential for reliable imaging of the metabolism of a hyperpolarized agent with sufficient SNR to observe lactate, alanine, and bicarbonate. Excellent resolution is observed for the spectroscopic components, consistent with J_{CH} dominated line-width (an advantage for high-field). Distinct metabolic patterns were observed for spectra taken from the rat kidney, muscle and liver that are consistent with the metabolism of these tissues. For example the kidney demonstrates high levels of polarized pyruvate and its metabolite lactate and bicarbonate due to the filtration of these compounds in the renal pelvis.

References:

1. Ardenkjaer-Larsen, J, Fridlund, B. et al PNAS (2003) 100; 10158-10163.
2. Golman, K, Ardenkjaer-Larsen et al PNAS (2003) 100; 10435-10439.