Multi-Coil Metabolic Imaging, with SENSE reconstruction, of Hyperpolarized [1-13C] Pyruvate in a Live Rat at 3.0 T

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Introduction: Metabolic imaging *in vivo*, with hyperpolarized carbon substrates, enables spatial and temporal resolution of biochemical processes in both normal and diseased states (*1*), as is now documented in many studies of large and small animals. A naturual evolution in technique is towards parallel imaging, and Hancu and coworkers (*2*) have shown examples with SENSE (*3*) and GRAPPA (*4*). We present here multi-channel metabolic images of hyperpolarized [1-^{13}C] pyruvate in a live rat, with both full k space, and reduced field of view acquisition, the latter followed with SENSE reconstruction. The resulting ^{13}C metabolic images show high correlation with anatomic (proton) images taken in the same exam, without moving the animal.

Methods Polarizer and compound: Samples of 32µl [1-^{13}C] pyruvic acid (Isotec) and 15mM OX63 trityl were polarized and dissolved using a Hypersense DNP polarizer (Oxford Instruments), as described eleswhere (*5*). The measured polarization was 18%.
MR hardware: NMR scans were performed on a GE signa 3T scanner with multinuclear package. Custom coils (Fig. 1) were used: a ^{13}C Helmholtz pair (in clamshell geometry) for transmission, with capacitive coupling mesh and proton blocking; and a recieve array of 3 elements with proton blocking and preamps on board. The receive coil array was positioned as shown in Fig. 1, with its elements ordered transverse to the static field direction, i.e. left to right. Proton blocking of the carbon-tuned resonators allowed proton imaging with the system body coil.
Animal handling: Animal studies were carried out under a protocol approved by the local Institutional Animal Care and Use Committee. Normal Male Sprague-Dawley rats were placed on a heated pad and anesthetized with isoflurane (2-3%).
Chemical Shift Imaging (2D): Two coronal ^{13}C 2D chemical shift image (csi) datasets, were acquired from one animal, following tail-vein injections (of duration 12 s) of a 2.5 ml bolus of hyperpolarized pyruvate solution, about 1 hour apart. The field of view (FOV) for the first injection was 16 cm x 10 cm, and 8cm x 10 cm for the second. In both cases, the spatial encoding matrix was 16 x 10, with 16 encoding steps in the head to tail direction. Data acquisition started 25s after the start of the injection. A pulse-acquire sequence was used, with 10 degree flip angle and 80ms TR (5000Hz/256pts readout). Both datasets were acquired from a 1cm thick slab. Coronal T2-weighted ^{1}H MR images were also acquired with the system body coil, without moving the animal, or the carbon transmit and recieve coils, to allow registration of the ^{13}C 2Dcsi data to the anatomy. At the end of the experiment, the animal was replaced with a phantom consisting of a sealed plastic bag filled with corn oil, and a 3D csi data set was acquired to allow construction of coil sensitivity maps for reconstruction, which was performed with reduction factor R = 1 for the 16 cm FOV, and R = 2 for the 8 cm FOV.

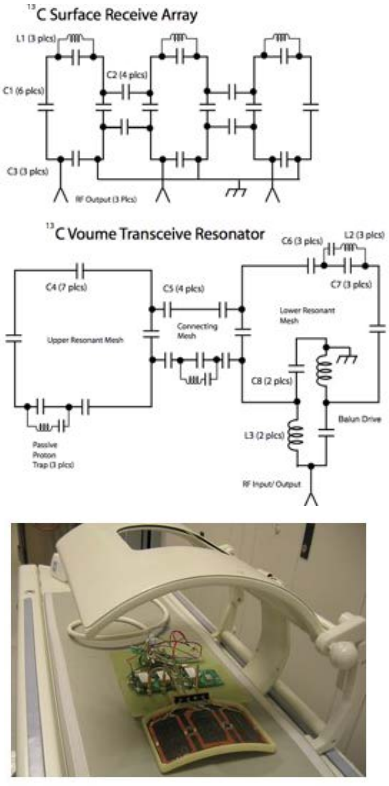

Fig. 1

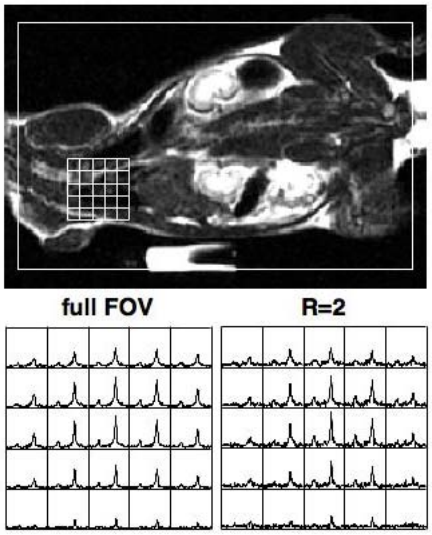

Fig. 2

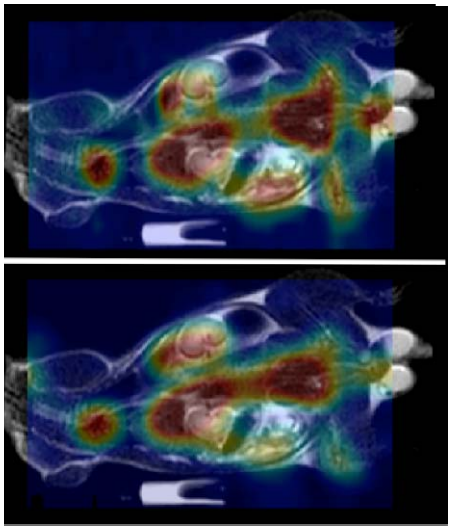

Fig. 3

Results and Discussion: Figure 2 shows the ^{13}C spectra from the heart and vicinity, as indicated by the spectral grid (white lines) in the proton image. The full field of view (FOV) reconstruction, zero-filled to obtain isotropic voxels, is on the left; the reduced FOV (i.e. SENSE) reconstruction is shown to the right. Note the improved spatial definition of the heart in the LR direction of the spectral grid (SI direction in the rat.) Figure 3 shows the color maps of pyruvate metabolic images overlaid on the proton anatomic image (in monochrome), with SENSE reconstruction (R = 2 enhanced resolution) above, and full (FOV) reconstruction (below). The bright reference sample (syringe filled with [1-^{13}C] lactate) appears at the bottom of each figure. The heart, kidneys, and portions of the liver are clearly visualized in the pyruvate image.

References:
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