

SNR comparison between CSI and spectral-spatial EPI acquisitions for hyperpolarized ^{13}C metabolic imaging

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Audience: Scientist and clinicians interested in the translation of hyperpolarized ^{13}C metabolic imaging.

Introduction: A first in human hyperpolarized ^{13}C metabolic imaging study was recently conducted in prostate cancer patients¹. In this study, traditional chemical shift imaging (CSI) was utilized to acquire 2D or 3D spatially localized hyperpolarized $[1-^{13}\text{C}]$ pyruvate and $[1-^{13}\text{C}]$ lactate images from a single imaging window. While CSI is a robust technique and has been shown to provide hyperpolarized ^{13}C metabolic images with high SNR², its relatively long readout and overall scan time limits its flexibility and the information that can be obtained. Imaging based approaches utilizing selective excitation of a specific metabolites or IDEAL reconstruction of multi-echo data have been developed for dynamic hyperpolarized ^{13}C metabolic imaging^{3,4}. These techniques enable acquisition of temporally resolved ^{13}C metabolic imaging data throughout the time course of substrate infusion and its metabolic conversion. However, it has not yet been shown that the SNR for the relevant metabolic product (such as ^{13}C lactate) obtained using the imaging approaches can match that shown by the CSI approach. Given the modest ^{13}C lactate SNR obtained in the first-in-human study, it is important to evaluate the more advanced imaging approaches from the perspective of achievable SNR. In this study, a comparison was performed *in vivo* between a spectral-spatial EPI sequence designed for hyperpolarized ^{13}C metabolic imaging of the human prostate and the standard 2D CSI technique.

Methods: **Hardware and agent:** All studies were performed using a 3T GE MR750 scanner (GE Healthcare) with a dual-tuned $^1\text{H}/^{13}\text{C}$ birdcage rat coil. A SPINLab polarizer (GE) was used to polarize the substrate. Neat $[1-^{13}\text{C}]$ pyruvic acid (Isotec) doped with 15mM of OX63 radical (Oxford Instruments) and 1mM Gd chelate (Prohance®, Bracco International) was polarized and then dissolved with a $\text{H}_2\text{O}/\text{EDTA}$ solution and neutralized with a NaOH/TRIS buffer post dissolution. ***In vivo* experiments:** Healthy Sprague Dawley rats (Harlan Laboratories) were used in this study. An imaging pulse sequence using spectral-spatial excitation and flyback EPI readout described previously³ was used to acquire images of $[1-^{13}\text{C}]$ pyruvate and $[1-^{13}\text{C}]$ lactate from a 3D volume (8 cm x 8 cm x 12 cm; 16 x 16 x 12 matrix) that includes the rat kidneys. 16 temporally resolved imaging datasets were acquired for each metabolite with a 4 s temporal resolution. The flip angle was 2.5 and 30 degrees for pyruvate and lactate, respectively, with 12 excitations performed for each 3D dataset. A pulse-acquire chemical shift imaging pulse sequence was also used² to acquire 2D CSI data from a slice (1 cm) through the rat kidneys, 5000 Hz/ 256 pts readout, 80 ms TR) and the FOV, in plane encoding matrix and slice thickness matches that of the imaging data. Data were acquired from the same animal using both pulse sequences following separate infusions of hyperpolarized $[1-^{13}\text{C}]$ pyruvate (2.3 cc, 12 s injection). Data acquisition started at the same time as the start of the infusion for the Sp-Sp EPI imaging pulse sequence, but a 20 s delay was used for the CSI acquisition.

Results and Discussion: Hyperpolarized ^{13}C Lactate images from the slice containing rat kidneys using the Sp-Sp EPI acquisition (center) and the CSI acquisition (right) are shown in Fig. 1, along with the ^1H anatomical image from the same location (left). The Sp-Sp EPI image with the temporal maximum lactate signal in the kidney is shown. The data from both acquisitions were zero filled to 32 x 32 points in the RL and AP dimensions, and Fourier transformed without k-space filtering (CSI data was apodized in time domain with a 20 Hz Gaussian filter). SNR was calculated using the highest signal in the left kidney and standard deviation from a 7 x 7 voxel region in the upper left hand corner of the image as noise. Higher SNR was obtained in the CSI data (51) as compared to the Sp-Sp EPI data (23). Note that the data being compared correspond to an acquisition time of 20.5 seconds for CSI and 300 ms for Sp-Sp imaging of one metabolite. Mild spatial distortion was also observed in the EPI data. While the CSI acquisition may be more immune to imaging artifact related to field inhomogeneity and eddy currents, and can achieve higher SNR as compared to the time-resolved 3D imaging acquisition, the temporally resolved imaging data may be more robust against perfusion changes in individual patients since no fixed imaging window and delay time is required for this approach, and 3D coverage is achieved. Furthermore, summing the metabolite images from the multiple time-points improves the SNR of the Sp-Sp imaging approach by a factor of 2 or more⁵.

Conclusions: A spectral-spatial EPI dynamic ^{13}C metabolic imaging pulse sequence was compared to the standard single time-point CSI acquisition *in vivo* using $[1-^{13}\text{C}]$ pyruvate. While CSI data provided higher ^{13}C lactate SNR compared with a single time-point in the Sp-Sp EPI data (from the time-point with highest signal), the dynamic imaging approach may offer more flexibility and information. By summing time-points, the 3D Sp-Sp acquisition will likely provide similar SNR as the 2D CSI used in the first-in-human study.

References: 1. Nelson SJ et al. *Sci Transl Med*. 2013;5(198):198ra108. 2. Kohler SJ et al. *MRM*. 2007;58:65-69. 3. Lau AZ et al. *NMR Biomed*. 2011;24(8):988-96. 4. Wiesinger F et al. *MRM*. 2011;68:8-16. 5. Cunningham CH et al. *NMR in Biomed*. In press.

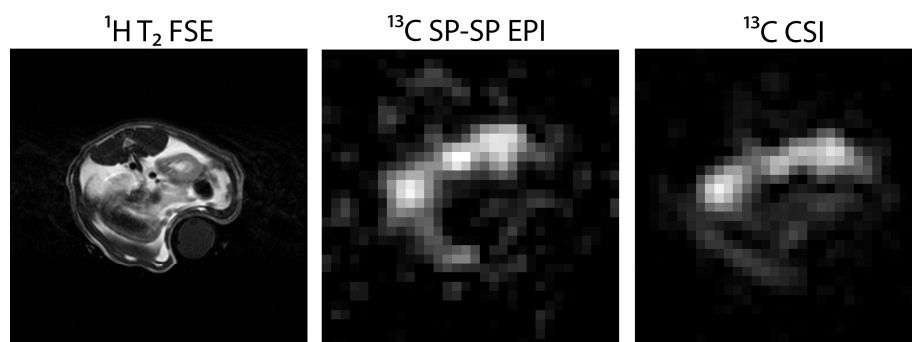


Figure 1. ^{13}C lactate images acquired from the same slice through the rat kidneys using the Sp-Sp EPI acquisition (center) and the CSI acquisition (right) as well as the reference anatomical image (left).