^{13}C PASADENA Imaging *In Vivo*

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OBJECTIVE: The objective of this work was to determine the feasibility of performing repeated measurements of spatial (3D imaging) and spectral (1D chemical-shift) distributions following administration of a hyperpolarized 13C substrate in order to determine spatially localized metabolic kinetics (e.g. spatial distribution of tumor metabolism of 13C-pyruvate to 13C-lactate).

BACKGROUND: Reeder et. al [1] first demonstrated the ability to derive high spatial resolution chemical-shift images from multiple sequential gradient echoes acquisitions at echo times shifted by Δt. Recently Wieben et. al.[2] proposed a much faster method for acquiring both the spatial and spectral information in one scan using a multiple-echo 2D balanced SSFP (FIESTA) imaging technique. The Nyquist frequency (N_f) for this technique is determined by the echo spacing, Δt, where $N_f=1/(2\Delta t)$, and the spectral resolution (Δf) is determined by $\Delta f = 1/(N \Delta t)$, where N is the number of acquired echoes, The multiple-echo 2D FIESTA technique is fast, has relatively high spatial resolution, and is able to adjust the number of echoes (N) and the echo spacing (Δt) to provide the desired spectral resolution. We have implemented a multiple gradient echo 3D FIESTA technique in order to provide the increased SNR necessary for imaging hyperpolarized ^{13}C labeled compounds (products and substrates) at low concentration.

MATERIALS and METHODS: All ^{13}C imaging was performed in a transmit/receive ^{13}C surface coil designed and built in our laboratory. All imaging was performed on a 1.5 T General Electric Signa MR scanner operating with version 9.1 software. The manufacturer's standard 3D FIESTA pulse sequence was modified to allow multi-nuclear and multiple-echo imaging (ME-3DFIESTA). The animal preparation was approved by the Institutional Animal Subjects Committee. A rat was anesthetized and a catheter placed in the jugular vein. The rat was positioned supine on the ^{13}C surface coil. A sphere containing 3M ^{13}C-acetate was placed next to the animal to serve as a chemical shift, spatial, and ^{13}C-concentration reference. ME-3DFIESTA imaging was performed with a 16 x 64 x 64 matrix giving isotropic 7 mm spatial resolution, BW=62.5 MHz, 8 echoes, 1.344 ms echo spacing, Δf =93 Hz, N_f=372 Hz, and TR=14.5 ms for a 17 second scan time. Repeated Multiple ME-3DFIESTA acquisitions were obtained before during and after injection of 50 mM of ^{13}C-hydroxyethylpropionate and ^{13}C-cis-fumarate simultaneously hyperpolarized using the PASADENA technique[3,4]. The spectral data was reconstructed with the technique reported by Leupold et. al.[5]

RESULTS: Selected slicse from the spectral data shown in Figures 1and 2 demonstrate the ability of the ME-3DFIESTA pulse sequence to provide both spatial location of the ^{13}C-labeled compounds. The sphere containing 3M ^{13}C-acetate is present at 0 Hz, the ^{13}C-hydroxyethylpropionate and ^{13}C-cis-fumarate appear at –279 and 93 Hz respectively as shown in Figure 1. Figure 2 shows a proton image (left) acquired from the same experiment as the ^{13}C metabolite map shown to the right. The ME-3DFIESTA technique was able to follow the spectral and spatial distributions of the ^{13}C-labeled compounds for over one minute.

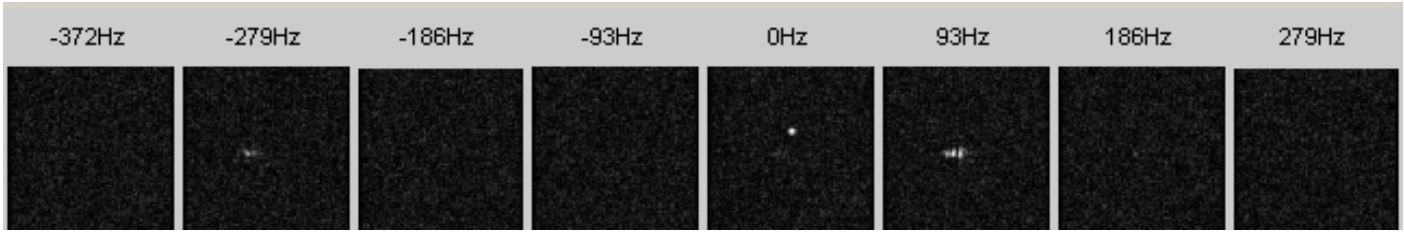

Figure 1

CONCLUSION: We have demonstrated the feasibility of performing repeated measurements of spatial (3D imaging) and spectral (1D chemical-shift) distributions following administration of a hyperpolarized ^{13}C substrate. This technique should allow investigators to determine spatially localized metabolic kinetics of hyperpolarized ^{13}C-labeled substrates.

REFERENCES: [1]Reeder et al., MRM 51, 35-45, 2004. [2] Wieben et al. Proceedings of the ISMRM, p. 2386, 2005 [3]Bhattacharya et at., Proceedings of the ISMRM, p 171, 2005 , [4]Bhattacharya et. al. 2005) *MAGMA*, 18.5 [5] Leupold et at., Proceedings of the ISMRM, p 102, 2005.

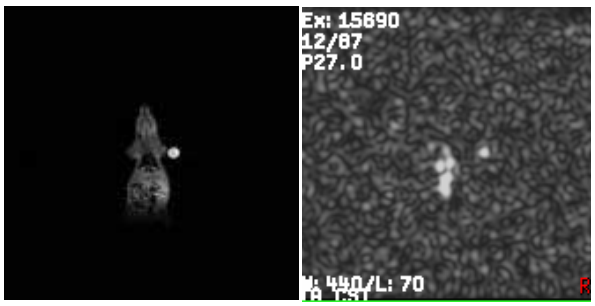

Figure 2