Fast Spatial-Spectral Imaging of Hyperpolarized 13C Compounds using Partial-Fourier Multiple Echo 3DFIESTA

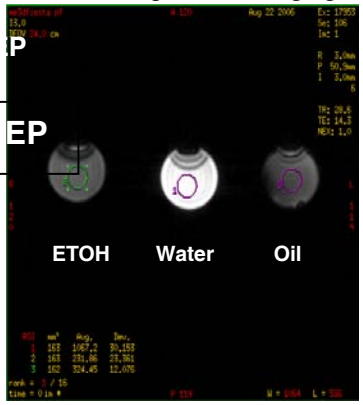
W. H. Perman, Ph.D. [1], P. Bhattacharya[2,3], A. Lin[2], J. Hovener[2,4], K. Harris[2], E. Chekmenev[2], V. A. Norton[3], D. P. Weitekamp[3], and B. D. Ross[2]

[1]Radiology, Saint Louis University School of Medicine, St. Louis, MO, United States, [2]MR Spectroscopy Division, Huntington Medical Research Institutes, Pasadena, California, United States, [3]A.A. Noyes Laboratory of Chemical Physics, California Institute of Technology, Pasadena, California, United States, [4]Medical Physics in Radiology, German Cancer Research Institute (DKFZ), Heidelberg, Germany

OBJECTIVE: The objective of this work is to develop a fast imaging technique for performing repeated measurements of spatial (3D imaging) and spectral (1D chemical-shift) distributions following administration of a hyperpolarized ^{13}C substrate in order to determine spatially localized metabolic kinetics (e.g. spatial distribution of tumor metabolism of ^{13}C-glucose to ^{13}C-glutamate).

BACKGROUND: The ability to derive chemical shift information from high resolution MR images was first proposed by Reeder et. al.[1] using a multiple sequential gradient echo acquisition. 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. It soon became clear that fast spatial-spectral imaging could be preformed in a single scan by acquiring the data using a multiple gradient echo balanced steady state sequence (FIESTA) using either a 2D[2] or 3D[3] data acquisition. 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 and 3D FIESTA techniques are fast, have relatively high spatial resolution, and are able to adjust the number of echoes and the echo spacing to provide the desired spectral resolution. We have further decreased the scan time while holding the spatial and spectral resolutions constant by implementing an asymmetric partial-Fourier multiple echo 3D FIESTA data acquisition technique (PFME-3DFIESTA). This PFME-3DFIESTA data acquisition technique is ideally suited for spatial-spectral imaging of hyperpolarized ^{13}C labeled compounds (products and substrates) where time is of the essence.

MATERIALS and METHODS: All ^{1}H and ^{13}C imaging was performed on a 1.5 T General Electric Signa MR scanner operating with version 9.1 software. The ^{1}H data were acquired with the standard head coil, the ^{13}C data were acquired using a transmit/receive ^{13}C surface coil designed and built in our laboratory. The manufacturer's 3D FIESTA pulse sequence was modified to allow multi-nuclear, multiple-echo imaging with partial Fourier sampling in both "z" and "y" phase encoding directions.



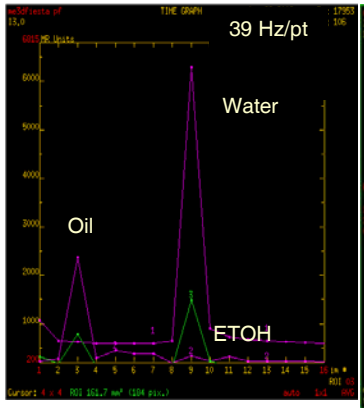


FIGURE 1: Full Fourier 16 x128 x 128 acquisition, ST=50 s

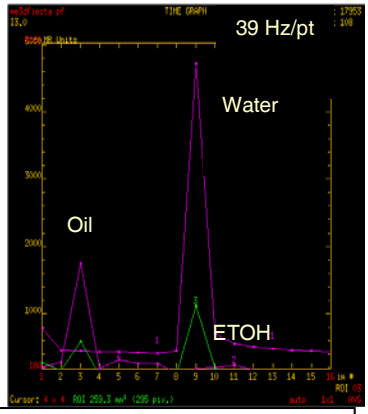
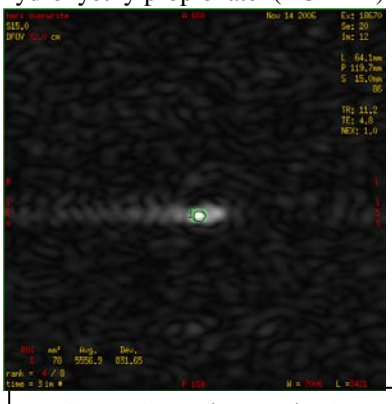


FIGURE 2: Partial Fourier 12 x 72 x 128 acquisition, ST=25s

RESULTS: PFME-3DFIESTA imaging of spheres containing ethanol (ETH), water, and oil was performed with full (Figure1) and partial (Figure 2) Fourier view sampling. Note, the spectra in Figures 1 and 2 are almost identical. The partial-Fourier has maintained the spatial and spectral resolution while reducing the scan time by 50%, with a concomitant sqrt(2) increase in the noise. Full and partial-Fourier PFME-3DFIESTA imaging was also performed on a syringe containing 5 mmol of ^{13}C-enriched ^{13}C-hydroxyethylpropionate (^{13}C-HEP) hyperpolarized using the PASADENA[4,5] technique. A selected chemical shift image and spectrum of this phantom are shown in Figure 3 demonstrating the ability of the PFME-3DFIESTA technique to provide spatial and spectral information of hyperpolarized ^{13}C-labeled substrates and products in a timely manner.



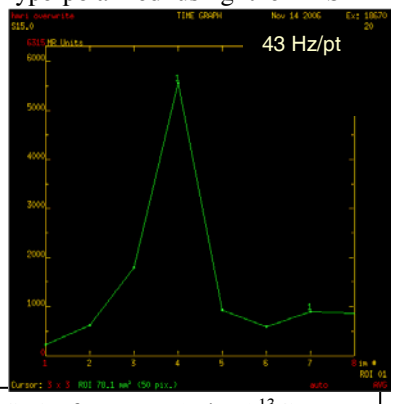


FIGURE 3: Partial Fourier 3DFIESTA of Hyperpolarized ^{13}C-HEP

CONCLUSION: We have demonstrated the feasibility of implementing a fast multi-nuclear, multiple gradient echo asymmetric partial-Fourier 3D FIESTA technique for the rapid measurement of spatial location and chemical shift of hyperpolarized ^{13}C-labeled substrates and products.

REFERENCES: [1]Reeder et al., MRM 51, 35-45, 2004. [2] Wieben et al. Proc. of the ISMRM, p. 2386, 2005.[3] Perman et at., Proc. of the ISMRM, p14:3216, 2006.[4]Bhattacharya et at., Proc. of the ISMRM, p 171, 2005.[5]Bhattacharya et. al. 2005; *MAGMA*, 18:245-256.