Projection Acquisitions for Dynamic Hyperpolarized ^{13}C MRI

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Introduction

MRI with hyperpolarized ^{13}C-labeled tracers is a valuable tool for probing pathways of cancer metabolism. Unfortunately, the hyperpolarized signal is short lived, decaying according to T_1 relaxation and losing magnetization with every RF excitation. Pulse sequences must be optimized to allow spatial, temporal, and spectral separation of tracers from their metabolic products. In this work, we evaluate the use of multislice projection acquisitions (PA) for hyperpolarized ^{13}C MRI, where dynamic time courses and spatial images from multiple metabolites may be simultaneously derived from one acquisition, reducing the cost and injected tracer volume associated with two separate hyperpolarized acquisitions. Two PA strategies were compared: echo planar spectroscopic imaging (EPSI) [1] and multiband frequency encoding (MBFE) [2]. Acquisitions and reconstructions were tested on phantoms and used to capture vascular input functions in the heart and dynamics of hyperpolarized pyruvate and lactate in tumors.

Methods

PA versions of EPSI and MBFE sequences were created by modifying a standard gradient echo sequence. For every RF excitation, *k*-space data are read along a unique projection angle, which is incremented according to the golden ratio (111.2°) to improve orthogonality between consecutive projections [3]. Sinograms generated by transforming data along the readout dimension are separated into multiple FE bands with MBFE or must be spectrally filtered [4] with EPSI to distinguish the metabolites. Dynamic signals can be extracted by summing the metabolite sinograms over all spatial positions. As a preliminary method, dynamic data were backprojected to generate metabolite images. Imaging was performed on a 7.0-T Bruker Biospec MRI system. Phantom data were acquired using a commercially available dual-tuned ^{1}H/^{13}C volume coil and animal data were acquired with a custom-built ^{13}C receive-only surface coil (two turns, 1.5-cm ID). Polarization of pyruvic acid containing OX063 (GE Healthcare) was performed with a HyperSense DNP polarizer (Oxford Instruments) as previously described [5].

Results

Spectrally-separated MBFE and EPSI images of ^{13}C-labled 3-M acetate and 8-M urea phantoms correlate well with their associated ^{1}H reference images (Fig.1). With EPSI, vascular input functions of hyperpolarized pyruvate were derived in the heart (Fig.2) and the conversion dynamics of hyperpolarized pyruvate into lactate were extracted from a mouse bearing a thyroid tumor (Fig.3). Similar data can be acquired with the MBFE sequence, although with lower spatial resolution (data not shown). Tradeoffs between the two PA methods involve spatial resolution, bandwidth requirements, echo time, SNR, and reconstruction complexity.

Discussion and Conclusions

We have developed and demonstrated two dynamic PA strategies for spatially and spectrally separating ^{13}C-labeled metabolites over time. This strategy is highly beneficial in that it avoids the requirement for two separate hyperpolarized acquisitions to derive spatial and dynamic information. This is particularly desirable due to the high cost for preparing the hyperpolarized tracer and the ability to limit the volume of tracer injected into the circulatory system. Future work will involve further sequence optimizations.

References

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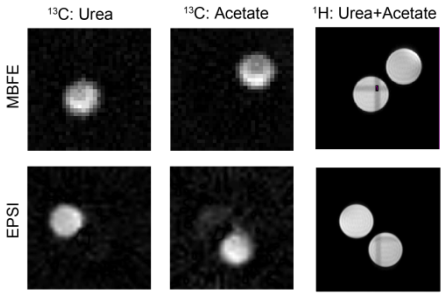

Fig. 1. PA versions of MBFE and EPSI can achieve spatial localization and spectral separation. *MBFE*: TE/TR = 10.4/300 ms, 2 bands, 32 read points, 300 projections, 3-cm FOV, 2.8 kHz BW, 2-cm slice, 90° flip angle; *EPSI*: TE/TR = 1.0/500 ms, ΔTE = 1.2 ms, matrix = 32 read points, 32 echoes, 50 projections, 3-cm FOV, 2-cm slice, 90° flip angle.

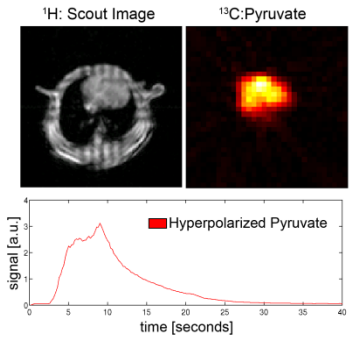

Fig. 2. PA data collected with EPSI produces spatially localized images and dynamic uptake curves of hyperpolarized pyruvate. TE/TR = 2.1/200 ms, ΔTE = 1.45 ms, 32 read points, 32 echoes, 300 projections, 3-cm FOV, 10mm slice, 30° flip angle.

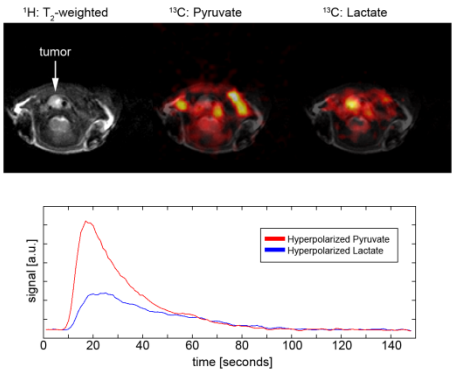

Fig. 3. PA EPSI data collected over the anaplastic thyroid tumor illustrates the spatial distribution of hyperpolarized lactate and pyruvate, while also providing dynamic metabolite curves. TE/TR = 2.3/1000 ms, ΔTE = 1.45 ms, 32 read points (interpolated to 128), 32 echoes, 200 projections, 3-cm FOV, 10mm slice, 30° flip angle.