In vivo real time metabolic imaging using frequency selective bSSFP and hyperpolarized compounds

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Target audience hyperpolarized media (gas and non-gas), sequence development, metabolism

Introduction

The specific constraints of hyperpolarized (HP) MRI are linked to the single-shot nature of the experiments due to the unavoidable decay of the enhanced polarization. Several acquisition strategies have been developed to rapidly image the spatial distribution of multiple compounds in order to track the metabolism of HP substrates *in vivo*, including EPSI[1], spiral CSI[2] or compressed sensing MRSI[3]. Some of the techniques use RF pulse properties to design interleaved acquisition of different substrates by frequency-specific excitation[4] or multi-band excitation schemes[5], whereas other approaches use the inherent frequency selectivity of MRI sequences using multi-echo[6] and/or SSFP based techniques[7]. From these last developments, we propose in this study an improved strategy for real time imaging of HP pyruvate and lactate in mice brain and liver.

Methods

A 3D bSSFP-based sequence (Fig.1) was implemented on a 9.4 T MR scanner. A quadrature dual tuned 1H/13C surface coil was used for transmit and receive. All the parameters were optimized according to our hardware limitations to achieve a spatial resolution of 1×1×5 mm^3. The sequence was first validated in a phantom composed of 2 concentric compartments (inner part filled with 250 mM [1-13C]lactate, and outer part with 250 mM [1-13C]pyruvate). The simulations gave a good chemical shift selectivity for an offset difference of 1450 Hz (Fig.2) and determined the optimal set of parameters: FOV 30×30×10 mm^3; matrix 32×32×2; TE/TR = 2.25/4.5 ms; 250 µs hard pulse with flip angle = 22°. The different metabolites were imaged using an interleaved approach with a delay of 1.5 s between scans.
The sequence was validated *in vivo* in mice after injection of hyperpolarized [1-13C]pyruvate (3M prepared with TEMPOL). Metabolic images were acquired in the mouse brain, as well as in the liver (shim and acquisition triggered with respiration). A Hamming filter on k-spaces was used.

Results and Discussion

Good selectivity between metabolites in the 2-compartment phantom is shown in Fig.2. Fig.3 illustrates the time course of the different metabolites in the entire brain. Fig.4 and Fig.5 show the metabolic time course in the liver.

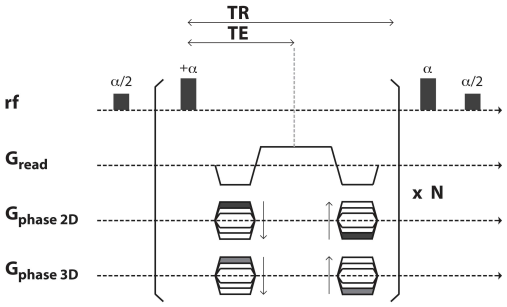

Fig.1: 3D-bSSFP sequence with preparation, flip-back modules and a non-RF alternated scheme for a sharper frequency selectivity at low flip angles.

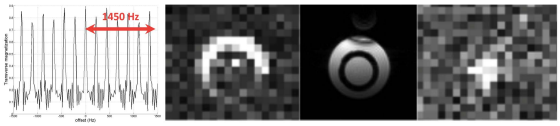

Fig.2: Selectivity given by simulations (graph). Validation in phantom (thermal signal): scout image and corresponding pyruvate (left) and lactate images (right).

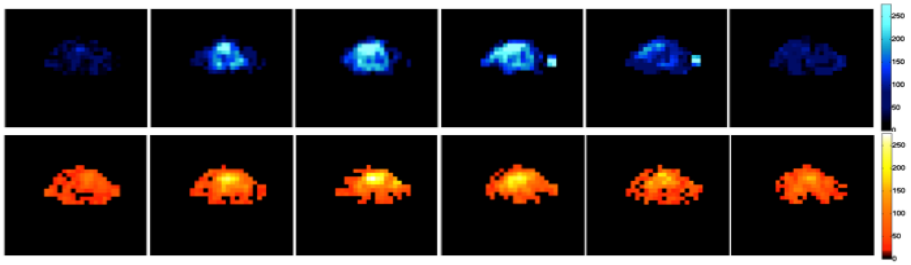

Fig.3: Time course (~ 10 s) of pyruvate (upper row) and lactate (bottom row) in a mouse brain.

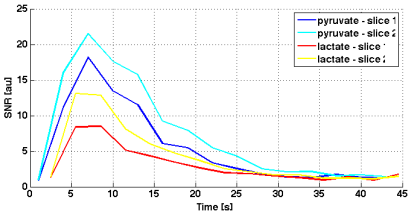

Fig.4: SNR over time inside the whole liver.

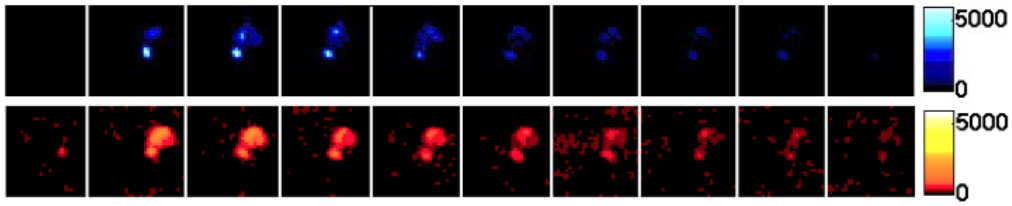

Fig.5: Time course (~16 s) of pyruvate (upper row) and lactate (bottom row) in a mouse liver (triggered acquisitions).

Conclusions

We showed in this study that with the proposed technique it becomes feasible to have a good spatial and temporal resolution for metabolic imaging with hyperpolarized compounds. However, robust analysis of the time-resolved information (e.g. exchange) would require the knowledge of the B1 excitation map, to avoid tedious multiple parameters fitting.

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