Parallel Spiral Chemical Shift Imaging for Metabolic Imaging with Hyperpolarised 13C

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Introduction: Parallel MRI (PMRI) has become an invaluable tool for reducing the acquisition time by using the spatially inhomogeneous sensitivity profiles of multiple receiver coils to reconstruct undersampled k-space data. This technique is particularly beneficial for imaging hyperpolarised compounds since their magnetisation is rapidly and irreversibly decaying. In this work, PMRI is used to improve the spatial resolution and spectral width of spiral chemical shift images of healthy rats in-vivo after injection of hyperpolarised [1-13C]pyruvate. An interleaved spiral PMRI sequence specifically designed for the requirements of hyperpolarised chemical shift imaging is presented.

Materials and Methods: An undersampled multi-shot spiral acquisition sequence was implemented partially based on [1]. After a gradient-spoiled, slice-selective excitation pulse, four identical low-resolution out-and-in spiral interleaves are recorded to determine the PMRI calibration kernel, followed by 12 identical undersampled spiral interleaves including rewinder gradients (nominal resolution 28x28, FOV 80mm, 64ms total acquisition time). This trajectory is subsequently rotated and temporally shifted with each new excitation to cover the entire k-space at sufficient spatial and spectral resolution. For this work, a total of 6 excitations (3 rotations with 2 different echo times, spectral width 520Hz) are used to encode a complete metabolic dataset. The spectral width is determined by the length and thus by the resolution and sampling density of a single interleave. By using parallel imaging, the spectrum can be recorded without aliasing at a higher resolution compared to a fully sampled acquisition with the same number of excitations. Images of healthy male Wistar rats (10mm slices through kidneys and liver, T_R = 250ms, flip angle = 10°, 32 time steps) were collected after tail-vein injection of 2.5ml/kg-80mM hyperpolarised [1-13C]pyruvate solution on a 3T HDx scanner (GE Healthcare, Milwaukee, WI) using a four-channel receiver coil (Rapid Biomedical, Würzburg, Germany). A Hypersense DNP polariser (Oxford Instruments, Abingdon UK) was used for 13C polarisation. Undersampled data were reconstructed using a combination of least-squares solution matrix inversion (LSCSI) [2] for chemical shift separation and SPIRiT [3] for parallel imaging reconstruction. The SPIRiT calibration kernel was averaged over several acquisitions to reduce artifacts and improve SNR.

Results and Conclusion: Results in kidneys are in good agreement with a proton GRE anatomical reference image (Fig. 1). In addition, metabolic images show high SNR and similar distribution of metabolites as compared to a fully sampled IDEAL Spiral (ISPCSI) [4] reference measurement from a second injection reconstructed with a gridding interpolation. Compared to a gridding reconstruction of the same data, SPIRiT-reconstructed parallel spiral CSI almost completely eliminates aliasing noise. In conclusion, a flexible and efficient spiral CSI implementation for parallel imaging of hyperpolarised [1-13C]pyruvate and its metabolites has been demonstrated.

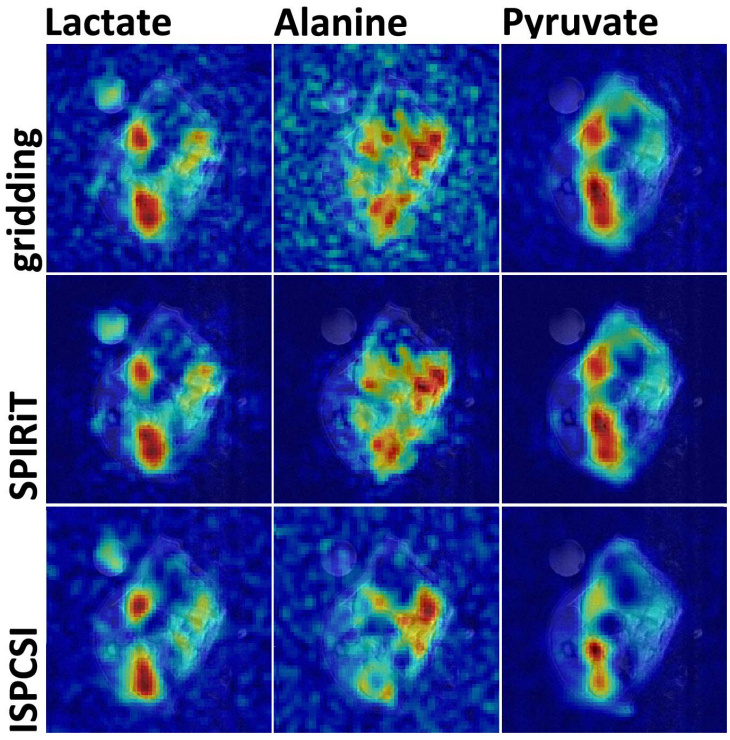

Fig. 1): Comparison of a single time step from parallel spiral CSI / ISPCSI reference measurement through the rat kidney

Depending on the desired spectral width and spatial resolution, the number of rotations and echo shifts can be adapted specifically to the desired application, along with the ratio of calibration to imaging spirals. In principle, also a single-shot approach would be possible for few metabolites and narrow line widths. It further provides optimal support for kernel averaging. Out-and-in calibration spirals reduce motion and flow artifacts and do not loose magnetisation during gradient rewinding [5].

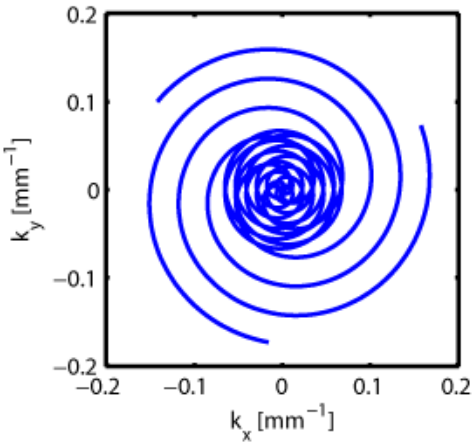

Fig. 2): Complete trajectory after 3 rotations with fully sampled k-space center region and 3-fold undersampled outer region

References: [1] Mayer D, 2009, MRM ;62:557-564. [2] Reeder SB, 2004, MRM ;51:35-45. [3] Lustig M, 2010, MRM ;64:457-471. [4] F. Wiesinger, et al. MRM, in press. [5] Kim D, 2009, MRM ;61:457-461.

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