Methods for Fast Imaging of Hyperpolarized Nuclei

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The advent of hyperpolarized liquids as an MR contrast agent [1] has opened up many new possibilities for metabolic imaging and created much excitement in the field. However, the unique properties of this contrast agent creates many challenges for the pulse-sequence designer. The biggest concern, of course, is that the polarization is not replenished by T1 recovery, so careful tipping of the magnetization by a limited number of RF pulses is essential. Furthermore, the particular T1 and metabolic conversion rates of interest must be taken into account when considering the details of an acquisition scheme.

For many applications, the goal is to measure the metabolic conversion of a substrate into downstream metabolic products, commonly the conversion of [1-^{13}C]pyruvate to lactate, alanine and bicarbonate. In the simplest approach, this is done by acquiring an FID and performing a Fourier transform to visualize the 13C spectrum [1-3]. The strategy makes no assumptions about the components that will be observed in the spectrum except for the required spectral bandwidth and resolution. However, for certain challenging applications such as cardiac metabolic imaging, conventional spectroscopic acquisitions are insufficient, particularly when volumetric (multi-slice) coverage is required.

When the particular frequencies that will be in the spectrum are known a priori, which is often the case, there are many other options for acquiring the spectral information in a more efficient manner. Iterative decomposition methods, where constrained model fitting is used to separate the frequency components within each voxel [4,5] generally require fewer k-space traversals (echos) than CSI, which facilitates higher spatial resolution since there is more time to get further from the k-space origin during each echo. However, the longest duration per k-space traversal is possible with the use of spectrally-selective RF pulses to excite single metabolites [7-10] This results in a single spectral component (e.g. [1-^{13}C]lactate) that can be imaged with conventional fast imaging methods such as a single-shot k-space trajectory. With a dominant long-T2 component observed from *in vivo* signals [6], these long-duration readouts can result in high efficiency.

In this presentation, the constraints on pulse sequence duration and timing (T1, T2, T2* and metabolic conversion rates) will be used as a framework for the discussion of the various pulse-sequence strategies that have proven successful in the literature. This includes the decoding of spectral information through the FFT, as in conventional spectroscopy, vs. decomposing the spectral components via parametric fits (e.g. IDEAL). A particular focus will be applied to strategies where the excitation of single resonances, using spectral-spatial RF pulses, has been used to sample the spectral information. The design and application of efficient k-space trajectories such as spiral and EPI, as well as the use of variable tip-angle approaches will be discussed.

References

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