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Feasibility of Adiabatic Refocusing Pulse for Detecting 2-Hydroxyglutarate using Proton Single-voxel Magnetic Resonance Spectroscopy at 7 Tesla

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An ultra high-field whole-body NMR system is the new medical appliance to investigate a human body and its metabolism noninvasively. In principle, higher magnetic field brings many benefits such as improved resolutions in MRI and enhanced signal-to-noise ratio in MRS. However, challenges still remain with the application of high-field MRI and MRS, and many hardware and software improvements must be accomplished before the system could put in use for clinical investigations. One of the serious problems in high-field whole-body MRS, for instance, is the inhomogeneity of so called B0-and B1-field where even a small fluctuation of magnetic field in the system can exceedingly deteriorate the quality of a MR spectrum.

In order to find a way to overcome the challenge, first of all, the basic concept of NMR was reviewed and some key points in improving the outcome of MRS were highlighted in the first chapter. Creating and modifying a MRS sequence is the essential path to improve the quality, and the adiabatic radiofrequency pulse was introduced because it seemed to be a promising tool to transcend the effects of the field inhomogeneity at a high-field NMR system. The adiabatic RF pulses manipulate the nuclear spin magnetizations in an unique way so that B1-field inhomogeneity over a large volume (e.g. inside the RF volume coil) becomes negligible.

The adiabatic RF pulses are implemented in the 1H single-voxel spectroscopy sequence called semiLASER, and the sequence was installed in the 7T whole-body system at DKFZ. The modification steps that were applied to the sequence code were explained in the second chapter and the prescan process was also explored including the transmitter voltage adjustment with B1-field mapping, B0-field shim by FASTMAP, and WET water suppression. After the sequence code was optimized and successfully installed, several types of chemical solutions (i.e. phantoms) were prepared to examine the feasibility of semiLASER 1H SVS sequence at the 7T whole-body system.

To begin with, the localization of the volume of interest (i.e. voxel) was examined with the phantom containing the equal concentration of four different chemical solutions (e.g. NAA, Cr, Cho, and Lac) in a separate compartment. After the quality of the volume localization was tested, the effects of the voxel location in an inhomogeneous B1-field were accessed with the homogeneous chemical solution containing some signature metabolites that would appear in a MR spectrum of the human brain. The results using semiLASER sequence were compared with the spectra acquired with PRESS SVS sequence to examine the advantages and disadvantage of using adiabatic RF pulses.

Lastly, semiLASER 1H SVS in the phantom containing a small volume of NAA and 2-hydroxyglutarate revealed the possibility of using adiabatic RF pulses to detect

a metabolite of low concentration inside the human head. While the implementation of the adiabatic sequence at a high-field whole-body scanner is difficult and the use of adiabatic RF pulses may cause a conflict with the specific absorption rate limit, the results revealed that it could be a great advantage to use semiLASER SVS sequence in order to have a better control of the phase, produce more consistent SNR at different locations, and assess the concentration of a cancer marker metabolite such as 2HG in the brain.

The implementation of semiLASER 1H SVS sequence at 7T even opened up the door to use MRS for in vivo studies of the human head at the ultra high-field whole-body system. Careful adjustment of the sequence parameters and multiple testings should be performed, but the use of 7T whole-body system for MRS seems ever so promising with the existence of semiLASER sequence. The clinical investigations with the high-field whole-body NMR system only just began and the medical research using such system is expanding rapidly. The noninvasive method to understand the metabolism of the brain is highly enthralling and the high-field whole-body NMR system can make it possible to further promote cancer research.