Sequence Design for Prostate Spectroscopy with an External Transceive Phased Array Coil at 4T

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Introduction

Magnetic Resonance Spectroscopy (MRS) has been shown to provide diagnostic information for prostate cancer. Specifically, MRS maps of citrate and choline concentrations in the prostate can be used as cancer risk indicators [1]. Here, a new protocol for prostate MRS is presented that combines a novel *external* RF coil, and an adiabatic pulse sequence at 4 Tesla. Conventional prostate MRS is performed with an endorectal RF probe which, while providing high signal to noise ratio (SNR) in part of the prostate, is accompanied by several drawbacks including patient discomfort, prostate deformation, RF signal inhomogeneity and local magnetic susceptibility artifacts. To avoid these difficulties and maintain high SNR in the prostate, an external transmit/receive (transceive) surface coil has been developed [2]. Prostate spectroscopy requires good localization, outer volume suppression(OVS) and lipid suppression. Conventional sequences, however, cannot reliably achieve these goals when a surface coil transmitter is used due to the inhomogenous RF field that is produced. Therefore, a pulse sequence was designed that tolerates B_1 inhomogeneity using Localization by Adiabatic Selective Refocusing (LASER) [3] and BISTRO [4] for outer volume suppression, both of which are fully adiabatic.

Methods

All experiments were performed on a whole body Varian/Siemens 4T Unity Inova system. To determine the J-modulation pattern of the strongly coupled citrate molecule for the LASER sequence, high resolution spectra of a 90mM citrate solution were acquired with an 18cm diameter hybrid birdcage coil at echo times ranging from 50-250 ms and the area under the citrate multiplet was measured at each echo time.

A pulse sequence (Figure 1) was designed that incorporates BISTRO for outer volume suppression, CHESS [5] pulses for water suppression, LASER localization, and fat suppression. Water suppression was achieved using 4 CHESS pulses that were strategically interleaved with the BISTRO sequence to minimize the T_1 relaxation between the OVS saturation pulses and the LASER excitation. To suppress lipids, a spectrally selective refocusing pulse was added following LASER localization that refocuses the spins from the metabolites of interest while suppressing residual signal from fat and water [6]. This pulse was generated using the Shinnar-Le Roux transform and optimized to have a bandwidth of ~1.8ppm. Care was taken to minimize the time of the pulse (10ms) while still affording sharp transition bands. The effectiveness of these sequence elements was tested using a phantom consisting of a ball of citrate solution immersed in corn oil to simulate the prostate and surrounding lipids. Large water bladders were placed on either side of the phantom, against the surface coil to simulate surrounding body tissue. With this configuration, RF pulse width and pulse power were optimized. To minimize power deposition, only 4 BISTRO slabs were applied with 16 asymmetric adiabatic HS pulses [7] per slab. The BISTRO parameters were optimized by observing the efficacy of the suppression technique when applied prior to a FLASH imaging sequence, and prior to MRS.

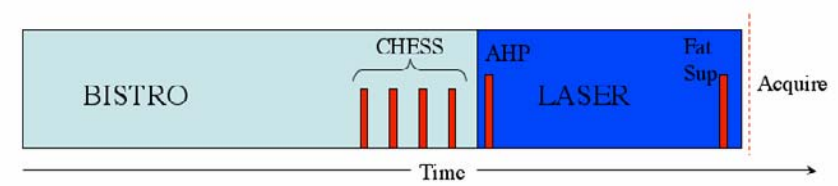

Figure 1. Block diagram of pulse sequence. BISTRO outer volume suppression is interleaved with CHESS water suppression prior to excitation. Fat suppression is applied after LASER.

Results

To maintain an upright citrate signal, the optimal echo times measured by LASER were between 50 and 98 ms. Citrate is also maximally inverted at 145ms, however it is less desirable to have an inverted citrate peak due to possible signal cancellation with adjacent metabolites. In vitro spectra acquired without BISTRO were contaminated by incoherent signal from the outer volume. To eliminate this contamination, BISTRO was applied to suppress the signal from the water bladders. Figure 2A demonstrates the position of the BISTRO OVS slabs in relation to the coil and phantom. Figure 2B demonstrates the suppression efficiency when BISTRO is applied. The large drop in signal intensity within the water bags demonstrates the effectiveness of the OVS. Approximately 90% of the signal is suppressed. In the spectroscopic data (Figure 2C), OVS has the effect of eliminating the signal contamination from the outer volume. The upright citrate signal is clearly visible at 2.5 ppm. Lipid suppression using a 10ms SLR refocusing pulse with spoiler gradients was effective at further reducing lipid and residual water signal (not shown), although 15 ms was added to the total LASER echo time.

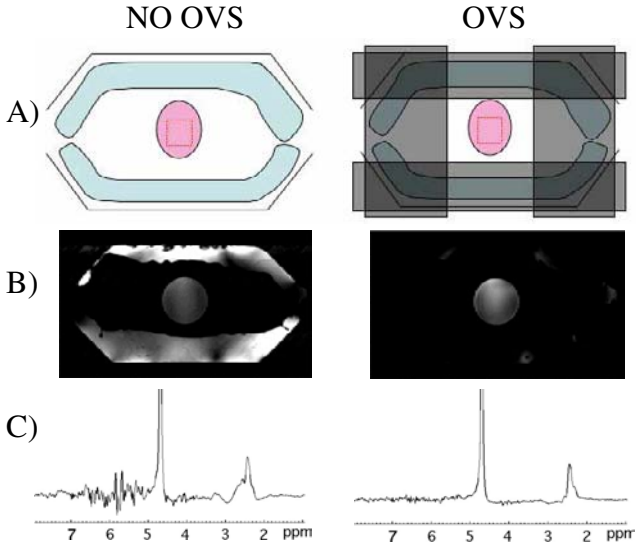

Figure 2. Results of BISTRO outer volume suppression. A) Cross sectional schematic of coil showing position of phantom and suppression slabs. B) Flash images with and without OVS. FOV=25x45 cm. TE=11ms. TR=5ms. Matrix= 128x128. C) LASER spectra (8cc voxel) with and without OVS. TE/TR=75/3200ms.

Discussion

A pulse sequence was designed for prostate spectroscopy to be used in conjunction with an external tranceive phased array coil. Although such coils present numerous advantages, they also present several challenges due to the high signal intensity immediately adjacent to the coil (on the periphery of the subject). However, the combination of BISTRO OVS and a spectrally selective refocusing pulse effectively eliminated signal artifacts in the spectrum. This sequence will be extended for use in human subjects and combined with chemical shift imaging to produce maps of citrate/choline for studying prostate cancer.

References

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Acknowledgements

Funding for this project provided by the Prostate Cancer Research Foundation of Canada.