High Field MRS Of Human Brain
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The advantages of high field MR have been demonstrated in a variety of MR acquisition modalities [1]. MRS can particularly benefit from substantial gains in signal-to-noise ratio (SNR) and spectral resolution at high field, enabling the quantification of numerous metabolites from small volumes-of-interest (VOIs) (Figure 1) [2-6]. Despite this potential, implementing spectroscopy in the human brain at high field bears multiple challenges. First, the power to generate $B_1^+$ increases approximately linearly with magnetic field [7]. As a result, the maximum magnitude of $B_1^+$ achievable with conventional volume head coils and available RF power are insufficient to generate conventional 90° or 180° RF pulses with bandwidths large enough to minimize chemical shift displacement errors in spectroscopy. Second, $T_2$ relaxation times of metabolites in the human brain are relatively short at this field [8, 9] and the SNR advantages quickly disappear with increasing echo times. Therefore, short echo times are critical for quantifying neurochemical profiles and are particularly important for reliable quantification of metabolites with coupled spin systems, such as glutamine (Gln), glutamate (Glu) and glutathione (GSH).

The use of adiabatic refocusing pulses has been proposed to partially overcome problems resulting from limitations in available $B_1^+$ magnitude at high field [10, 11]. Alternatively, high RF efficiency to maximize $B_1^+$ can be achieved by utilizing an array of transmit coil elements and optimizing the phase and/or magnitude of RF delivered to each transmit element ($B_1^+$ shimming) [12-14]. Similar approaches have been employed to acquire MRSI [15, 16] and single voxel MRS [4-6, 8] data from human brain at high field. The combination of a multichannel transceiver array coil and $B_1^+$ shimming enable the use of high bandwidth RF pulses and therefore a reduced chemical shift displacement artifact. This advances enables to achieve localization at short echo times, 8, 11 and 25 ms with STEAM [4], SPECIAL[6] and SEMI-LASER[6] sequences, respectively and lead to reliable quantification of metabolites with coupled spin systems.

Thus, the aim of this study is to provide an insight about our experience with high field $^1$H NMR spectroscopy of humans and highlight the most important features of pulse sequence design, data acquisition, data processing, metabolite quantification, and present some examples of applications at 3, 4 and 7 T.
References