Improved 3D PRESS MRSI at 7T Using B1 Field Mapping and Optimization of Transmit Gain

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Introduction: 3D PRESS MRSI has previously been implemented at 7T to image brain tumor patients using an eight-channel head coil [1]. However, PRESS spectra at 7T are susceptible to higher B_0 and B_1 inhomogeneities across the object, which influence the distribution of spectral peaks. Higher order shimming was applied previously to correct for the B_0 field variation [2]. In this study, we propose a method to reduce the B_1 inhomogeneity effects in 3D spectroscopic imaging by measuring the B_1 field variation using the double angle method (DAM) [3] and optimizing the transmit gain (TG) to achieve a more uniform flip angle distribution and improve the spectral peak definition across the PRESS box volume.

Methods: An MRS phantom containing brain metabolites and three volunteers were scanned on a 7T MR scanner (GE Healthcare, Waukesha, WI) using a volume transmit coil and an eight-channel receiver array (Nova Medical, Wilmington, MA). Two fast gradient echo images with flip angles of 20º and 40º (64x64x16, 3.44x3.44x5 mm resolution, TR/TE = 5000/3 ms, 5:40 min) were acquired to estimate the normalized B_1 field factors using the double angle method as,

$$b(x) = \frac{180 * \arccos\left(I_{40}(x) \Big/ 2 * I_{20}(x)\right)}{20 * \pi} \quad [1].$$

A proton-density weighted fast GRE image was acquired to estimate the eight channel coil sensitivities (64x64x31, 4.68x4.68x5 mm, resolution, TR/TE = 100/1 ms, 0.07 min). A dual echo GRE sequence was acquired to calculate the high order shimming currents to reduce the B_0 inhomogeneity for the spectra (256x256x64, 0.78x0.78x3 mm resolution, TR= 20ms, TE1/TE2=2/5ms, 1:15 min) [2]. 3D PRESS MRSI sequences were acquired using spectral spatial pulses (12x12x8, 0.8x0.8x0.8 cm nominal resolution, 0.5cc voxel size, TR/TE = 2000/90 ms, 5000 Hz, 2048 points, 17:12 min). Three spectral datasets were acquired from the phantom using TG=132, 119 and 90. Two PRESS spectra were acquired for each volunteer. The first spectral dataset was acquired using the automatic TG calculated by the scanner. The second spectra was acquired with a TG optimized for the median b(x) value across the PRESS box. The optimized TG was calculated using the TG of the GRE sequence acquired with a flip angle of 20º, and the transmitter output and B_1 relation ($\theta=\theta_0.10^{[(TG-TG_0)/200]}$) [4] as,

$$TG_{opt} = TG_{GRE(20)} + 200 * \log_{10}\left(\frac{B_{1\max}^{PRESS}}{b * B_{1\max}^{GRE(20)} * 10^{xmtaddscan(GRE(20))/200}}\right) \quad where \quad b = median(b),\ B_{1\max}^{GRE(20)} = 0.073 * 20/90,\ xmtaddScan(GRE(20)) = 190.849,\ and\ B_{1\max}^{PRESS} = 0.198 \quad [2].$$

The spectra were processed and quantified using in-house software [1] to estimate the median signal to noise ratio (SNR) of Cho, Cr, NAA and lipid.

Results: The median normalized B_1 field factors (b) were 1.11 [0.81, 2.01] for the phantom and 1.15 [0-1.90], 1.29 [0-2.32], and 1.22 [0-1.93] for the three volunteers, respectively. The mean (±std) SNR of the NAA peak was 230.9±114.7, 248.4±164.3 and 207.7±171.3 for the phantom spectra acquired with a TG of 90, 119 and 132, respectively. The highest mean NAA SNR was observed when the TG was optimized to 119 for the phantom spectra. Figure 1 shows the b factors and the spectra acquired with TG=124 and TG=93 for an axial slice of volunteer 3. The spectra showed improved peak definition and less lipid contamination for all the volunteers. Table1 shows the transmit gains for the GRE and PRESS sequences along with the peak SNR values for the default and optimized spectra. The mean SNR increase of Cho, Cr and NAA were 75%, 50% and 34% respectively. The mean lipid was decreased by 33%.

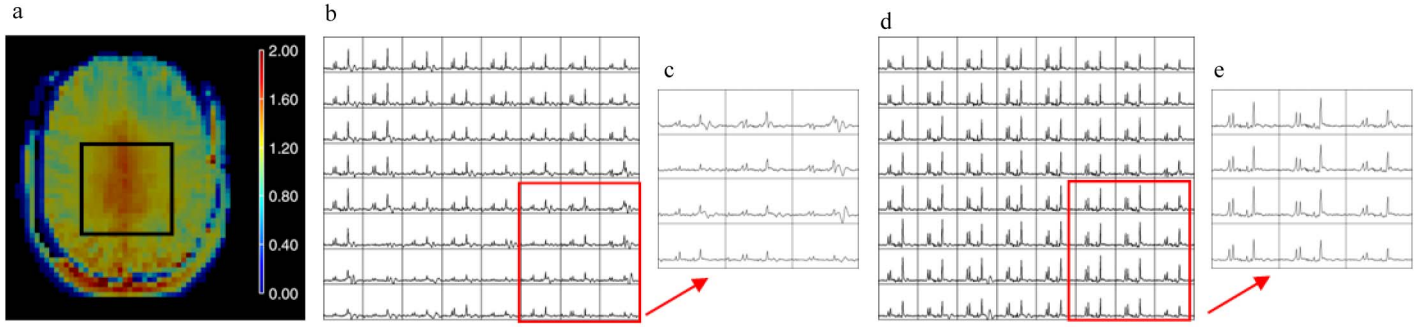

Figure1. (a) The b factor map for an axial slice of the volunteer brain with the PRESS box placed atop, (b) the spectra of the black box acquired with TG=124 and (d) with the optimized TG=93. The zoomed in spectra from 12 voxels corresponding to the (c) TG=124 and (e) TG=93 datasets.

Table 1. Transmit gain for the GRE sequence, median b value over the PRESS box, default and optimized TG for the two 3D PRESS MRSI and the mean±std of the SNR for Cho, Cr, NAA and lipid calculated from the default and optimized TG datasets.

	TG_{GRE}	TG_{PRESS}		med(b)	$TG_{default}$				$TG_{optimized}$			
		Default	optimized		Cho	Cr	NAA	Lipid	Cho	Cr	NAA	Lipid
volunteer1	85	120	98	1.15	18.2±15.6	32.1±23.5	80.4±44.4	58.4±52.9	30.3±14.9	44.9±21.9	96.±35.4	30.5±32.3
volunteer2	80	107	84	1.29	18.3±14.3	22.2±21.2	54.±31.4	22.3±17.	32.3±14.1	34.1±23.3	75.9±32.9	22.1±12.
volunteer3	84	124	93	1.22	22.3±16.1	34.±21.9	67.3±37.1	18.3±8.9	41.±16.7	52.7±19.2	96.1±34.3	8.9±4.5

Discussion and Conclusion: This study demonstrated a transmit gain optimization method using a dual echo based B1 mapping technique for 3D PRESS MRSI that resulted in an improvement of peak SNR and spectral definition over the PRESS box as well as a reduction of lipid contamination. The specific absorption rate would also be reduced by lowering the transmit gain. This technique may be used as an alternative to using multiple transmitter channels to calculate the optimal flip angle when the required hardware is not available. Future studies will explore the effect of TG optimization on VSS pulses for outer volume suppression.

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