Reduction of systematic errors in MRSI based brain temperature mapping.

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Introduction

Linear temperature dependence of the proton frequency shift (PFS) has been widely exploited for MR thermometry. Of the two main approaches available 'Internal reference MRS thermometry' is reported to be insensitive to B_o inhomogeneity and susceptibility effects and has been employed to compute 'absolute' brain temperature maps using MR spectroscopic imaging (MRSI)[1]. However it can be argued that water suppression (WS) may introduce a systematic bias in the temperature maps acquired using MRSI. This study will focus on the nature of the bias and possibilities of correction.

Method

Using internal reference MRS, the temperature is estimated by computing the frequency difference between the temperature sensitive water peak and the temperature insensitive metabolite reference (NAA) peak. A series of 6 temperature maps were computed from MRSI data acquired using a commercial MRSI pulse sequence (GE-PRESS CSI) on a GE 1.5 T HDx scanner. For 5 MRSI scans the level of WS was varied by changing the delay (τ) between the frequency selective WS (CHESS) and PRESS localisation, while the no WS was employed for the 6th MRSI scan. The bandwidth of the 3 frequency selective RF pulses for CHESS was constant (75Hz) for all WS scans. A uniform, room temperature (20^{0}C) GE "SPECTRO" phantom was used and all measurements were made with consistent prescan settings. The phantom was kept in the scanner room for at least 24 hours prior to scanning. Details of MRSI acquisition and processing to obtain temperature maps are described by Marshall et al.[1] In addition, a B_o field map with the same pre-scan settings used for MRSI acquisitions was acquired. The entire set-up was repeated on different days to check for consistency.

Results

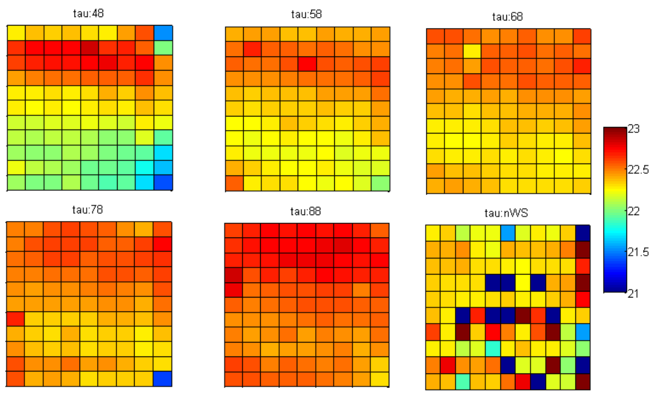

Figure 1: Temperature maps acquired at various levels of WS. Ranging from default (strong) WS (τ=48ms) to no WS.

τ (ms)	NAA Freq (ppm)	NAA Amp (I.U.)	NAA LW (Hz)	Temperature (^{0}C)	WS factor
48	1.89 (0.01)	297.7 (33.4)	1.4 (0.2)	22.4 (0.27)	85 (5.9)
58	1.89 (0.01)	291.2 (32.2)	1.4 (0.2)	22.4 (0.11)	24 (0.8)
68	1.89 (0.01)	294.7 (34.4)	1.4 (0.2)	22.4 (0.10)	14 (0.5)
78	1.89 (0.01)	289.2 (34.7)	1.4 (0.2)	22.4 (0.12)	10 (0.2)
88	1.89 (0.01)	289.1 (35.6)	1.3 (0.2)	22.5 (0.11)	8 (0.1)
nWS	1.89 (0.04)	268.8 (70.2)	2.6 (5.9)	22.0 (0.84)	1 -

Table 1: Mean (SD) of metabolites and temperature across the central voxels of the volume of interest (VOI).

An apparent systematic temperature gradient (approximately 0.6^{0}C, along the anterior-posterior axis of an axial slice) is evident in temperature maps acquired with WS as shown in Figure 1. A similar B_o gradient was also observed in the same direction. The apparent temperature gradient reduces when the delay (τ) is increased i.e. when weak WS is employed. This is evident from the temperature maps shown in Figure 1 and the lower SD of temperature across the VOI acquired using weak water suppression reported in Table 1. The temperature map acquired with no-WS is not uniform and higher SD for metabolite quantification is observed.

Discussion

The non water suppressed spectra usually have side bands or spurious echo artifacts[3] which may affect the accuracy of metabolites quantification (i.e. spectral fitting) and thus introduces variability in MRSI based temperature mapping. The B_o field inhomogeneity across VOI can cause suboptimal WS as the suppression pulses are likely to be at off resonance with water frequency, which varies across the VOI. This may introduce a small but systematic bias in the MRSI based temperature maps acquired with WS as reported in this study. This bias can be reduced by reducing the effectiveness of WS (i.e. using weak WS). The high scan time associated with traditional MRSI acquisition limits our ability to acquire both WS and no-WS MRSI data sets at the same time thus weak WS should be employed to reduce systematic errors in MRSI temperature mapping. However the temperature estimates using weak WS are hotter. This may be due to RF related heating[4] during successive MRSI acquisitions which may slightly increase the temperature of the phantom over the duration scan. The applicability of these results in-vivo is currently under-investigation. The use of fast MRSI pulse sequence with interleaved water reference (no WS) scan[5] may provide another solution and is currently being investigated.

References:

1. Marshall I et al, MRI 2006 24 (6) 699. 2. Childs C et al, MRM 2007 57 (1) 59. 3. Chadzynski G et al, MRI 2010 28 669-675. 4. Dong Z et al, MRM 2006 55 (6) 1441. 5. Ebel A et al, MRM 2005 53 465