Multivoxel Proton Spectroscopy for Non-invasive MR Thermometry: phantom comparison of PRESS and semiLASER-localized chemical shift imaging for temperature monitoring

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TARGET AUDIENCE: Investigators and practitioners pursuing MRI-derived methods of non-invasive in vitro or in vivo thermometry
PURPOSE: To establish the concordance between conventional and emerging multi-voxel proton spectroscopy techniques, as compared with previously validated single-voxel (SVS) approaches to proton resonance frequency chemical shift thermometry, using the water-NAA chemical shift [1]. We propose to compare the derived spatial temperature distribution as acquired from competing chemical shift imaging (CSI) techniques, with primary attention to spectral quality. Spectroscopy sequences utilizing slice selective radiofrequency may suffer from artifacts related to spatial displacement of compounds with differing chemical shifts (CS). Furthermore, corrective measures addressing such errors may themselves impart untoward consequences when acquiring a spatial spectral matrix. CSI semiLASER incorporates pairs of adiabatic slice selective refocusing pulses with heightened immunity to potential errors in CSI. We hypothesize that theoretical benefits inherent to the semiLASER-localized approach to CSI may offer enhancements in overall spectrum quality and thermometry [2,3]. We report herein an evaluation and test of this hypothesis using a phantom model.

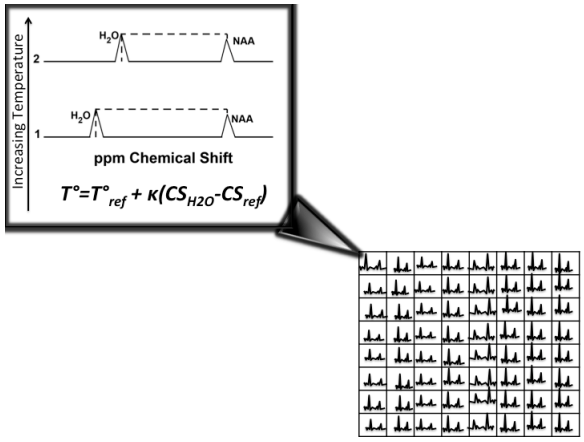

Fig.1 Schematic representation of chemical shift thermometry; an 8x8 multivoxel grid was prescribed for both standard and semiLASER CSI. Temperature is derived from temperature-dependent fluctuations in the water proton chemical shift (CS) compared with the stationary resonance of neuronal NAA

METHODS: All imaging was performed on a Siemens 3T TimTrio whole body system (Siemens Medical Solutions, Erlangen, Germany). A vendor-composed standard brain spectroscopy phantom (GE Medical System) was utilized for the spectroscopy experiments. Single- and multi-voxel spectroscopy (Fig.1) was performed using either vendor provided standard MRS sequences with point resolved spectroscopy (PRESS) localization or semiLASER CSI [2]. Specifically, SVS using a standard PRESS localization (TR/TE=1600ms/35ms; 128 averages; 1.5x2x2 cc voxel; acquisition time 3min 31s) was acquired at varying spatial positions across the phantom to correspond with the spatial coverage of the CSI volumes of interest subsequently prescribed. Standard 2D CSI was acquired using a 16x16 cm FOV and 8x8 cm VOI (TR/TE =1600ms/35ms; 7 averages; acquisition time ~8 min) producing an 8x8 voxel grid. Lastly, CSI semiLASER was acquired using identical parameters and at the same acquisition time as those defined for standard CSI. The scanner-equipped advanced automated shimming protocol was applied in all scans to obtain optimized shimming conditions. Proton spectra were acquired at the room temperature at equilibrium. Phantom temperatures were derived from the known temperature sensitivity of the difference between water and NAA chemical-shifts ($\Delta_{\delta H20\text{-}NAA}$), related to the temperature-dependent fluctuation in bound water fraction and water proton resonance approximated at 0.01ppm/°C [1]. All three approaches were averaged over 6 repeated measures. Differences between techniques were tested by one-way ANOVA between SVS and both CSI approaches across spatial positions. The two multi-voxel techniques were compared by two-sample t-test. Fitted line widths and SNR were reported for all multivoxel spectral data averaged across time at each spatial position. The obtained FID data were Fourier transformed and analyzed in LCModel V6.3 (*http://s-provencher.com/pages/lcmodel.shtml*). Chemical shifts of the metabolites of interest were assigned based on the center frequency from non-suppressed water resonance.
RESULTS: One-way ANOVA between techniques suggested consistency between the three approaches prescribed for chemical shift thermometry. Representative findings from a single spatial position revealed no significant differences in computed temperature using $\Delta_{\delta H20\text{-}NAA}$ (P=0.95) when comparing SVS, standard CSI, and semiLASER. Average temperatures across spatial positions derived from standard CSI and semiLASER demonstrated no significant differences (mean ± s.d. = 22.39±1.42 vs. 22.11±0.14, respectively, P=0.12); however, smaller standard deviations in measured temperatures were observed with semiLASER compared with standard CSI, which remained apparent both across spatial distributions as well as across repeated experiments. Mean fitted linewidths derived from the semiLASER experiment were found to be superior to that of standard CSI, (0.01ppm vs. 0.02ppm, P=0.03).
DISCUSSION: Both standard 2D CSI and semiLASER CSI may be accurate approaches to multivoxel chemical shift thermometry with the spectral phantom, which offers homogeneous and fairly uniform volume localization. Benefits inherent to the semiLASER technique including sharply defined excitation profiles, diminishing contributions from spurious remote signals, and greater immunity to chemical shift displacement errors, may provide for improved spectrum quality, reproducibility, and stability. Particularly such enhancements might be anticipated under non-optimal conditions, as indicated by consistently smaller standard deviations in computed temperatures and greater stability in measurements. In vivo comparison of the techniques would be beneficial towards establishing the superiority of semiLASER-localized approaches to multivoxel CSI thermometry, particularly in traditionally problematic regions such as the margins of the excitation volume.
CONCLUSION: Multivoxel approaches to chemical shift thermometry are feasible, and comparable to single voxel techniques; Advanced approaches to volume localization with semiLASER may be beneficial for in vivo applications.

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