Investigation of Region Specific Frequency Differences Between Water and N- Acetyl Aspartate Resonances Within The Human Brain

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Introduction:

The main advantage of ^{1}HMRS without water suppression is the availability of water signal which can be used as an internal reference in absolute quantification or for line shape correction [1]. However, recent studies [2, 3] showed that unsuppressed spectra may be also used for noninvasive measurements of physiological parameters, such as temperature and pH. These parameters can be estimated by measuring the frequency distance between resonances of water and endogenous metabolites like NAA Choline and Creatine [2, 4] or between water and exogenous substances like TmDOTP^{5-} (thulium Tm^{3+} paramagnetic ions with methylene phosphonate DOTP^{8-}) [3] or DSS (sodium 3-(trimethysilyl)propane- 1- sulfonate) [5]. Exogenous substances are more sensitive to the pH and temperature changes; however they have to be delivered to the body while endogenous metabolites are naturally present [2]. In our study we examined the frequency distance between water and NAA resonances. We performed in-vivo CSI measurements at the level of the lateral ventricles. The aim of this study was to determine if there are any regional differences in the water to NAA distance.

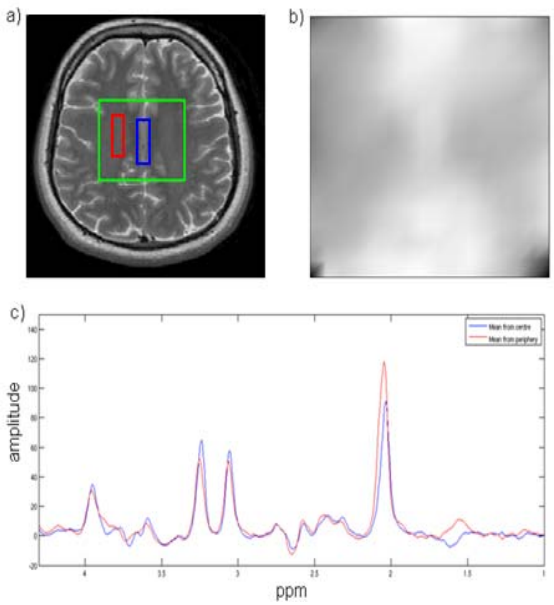

Figure 1: Differences in the frequency distance between Water and NAA resonances calculated for high resolution measurements. **a)** Localizer image with the area of the data acquisition, marked with the green square. **b)** Map of distance between water and NAA. **c)** Average spectra calculated from 10 voxels in WM (blue) and 10 voxels in GM (red)

Materials and Methods:

Unsuppressed spectra were acquired at 3T (TimTrio, Siemens, Germany) scanner at the level of the lateral ventricles. PRESS localization technique was used to obtain data from 11 healthy volunteers. Parameters of CSI acquisition were as follows: TR = 1500 ms, TE = 144 ms, CSI matrix size 24 x 24 voxels (interpolated to 32 x 32 voxels- 1 volunteer) and 16 x 16 voxels (no interpolation- 10 volunteers), nominal voxel size of 5 x 5 x 10 mm^3 (resolution 24x24) and 10 x 10 x 15 mm^3 (resolution 16x16). Number of excitations was 3 with weighted phase encoding scheme. Datasets were zerofilled from 512 to 2048 points. After chemical shift and baseline corrections the resonant frequency of water was calculated by fitting with a combination of Gaussian and Lorentzian functions. This was achieved with minimization of error function between the input data (spectrum) and the Gauss-Lorentz function by using Nedler-Mead simplex algorithm [6]. Resonant frequency of NAA was estimated with the same procedure, however after reduction of water signal and frequency modulated sidebands performed by convolution with Gaussian function and subtraction of water phantom FID from in vivo data [7]. All calculations were done with home developed software written under Matlab 2009b version.

Results:

Figure 1 shows the map of frequency distance between water and NAA peaks (fig. 1b) calculated over the whole excited volume (green square in fig. 1a). It can be seen that the distance between these two peaks is higher for voxels in the central part of excited volume (white matter- blue rectangle in fig. 1a) than for voxels from the periphery (gray matter- red rectangle in fig. 1a). This is confirmed by comparison of average spectrum (fig. 1c) from 10 central voxels (blue) with the one from 10 peripheral voxels (red) from one representative subject. NAA peaks has slightly different positions, while after chemical shift correction water signal in all spectra used to calculate the average spectrum was in the same position. Table 1 shows mean values of frequency distance between water and NAA calculated for all 11 volunteers. They were calculated from 3 voxels in the centre and 3 voxels in the periphery of the excited volume (lower resolution measurements) and from 10 voxels in the centre and 10 in the periphery (high resolution measurements). One can notice that very similar results were obtained for all examinations with the mean water to NAA distance of 2.665 ppm for voxels in the centre and 2.653 ppm for voxels in the periphery. Only in case of volunteer #10 and #11 these values are lower. However, the differences between water to NAA frequency distances for voxels in the centre and in the periphery (tab. 1, last column) in case of these two volunteers are comparable to those calculated for the rest with the mean value of 0.0126 ppm.

Table 1: Mean values of the frequency distance between water and NAA in voxels from WM (centre) and GM (periphery) together with their differences (GM – WM)

Volunteer #	Distance for WM [ppm]	Distance for GM [ppm]	Delta (GM – WM) [ppm]
1	2.6683	2.6532	0.0151
2	2.6691	2.6542	0.0149
3	2.6651	2.6556	0.0095
4	2.6643	2.6522	0.0121
5	2.6657	2.6548	0.0109
6	2.6670	2.6530	0.0140
7	2.6661	2.6530	0.0131
8	2.6667	2.6532	0.0135
9	2.6675	2.6562	0.0113
10	2.6587	2.6478	0.0109
11	2.6585	2.6456	0.0129
Mean +/- SD [ppm]	**2.6652 +/- 0.0035**	**2.6526 +/- 0.0032**	**0.0126 +/- 0.0018 (+/-14%)**

Discussion:

Our measurements showed that there are regional differences in the distribution of the frequency distance between water and NAA resonances. In all measured volunteers the values of the water to NAA distance were higher for white matter voxels than for voxels in gray matter (tab. 1). It could be explained by regional differences in temperature, pH values or other unknown physiological parameters. According to the previous studies [2, 3] this frequency difference would be approximately 1^{0}C however, calibration measurements in the literature [2, 3] were performed at 11.7 T. Additional calibration performed at 3T may be necessary for more reliable temperature measurements. In conclusion proton MRS without water suppression may be used not only for absolute quantification. It can be a promising tool for non-invasive measurements of important physiological parameters like temperature and pH.

References:

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