Quantitation error in ^{1}H MRS caused by B_1 inhomogeneity and chemical shift displacement at high B_0 field

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Target audience: Basic scientists or clinicians interested with either development or applications in magnetic resonance spectroscopy, especially with quantitation in MRS.

Introduction

High signal to noise ratio and good peak resolution are significant features in ^{1}H MRS at high B_0 field. These features may lead to high accuracy of quantitation of metabolites *in vivo*. However, voxel position of each peak differs during a slice selection more than at lower field due to large chemical shift displacement. In addition, B_1 inhomogeneity occurs due to dielectric effects in a body at high field. Then, a peak on a localized spectrum is weighted by different reception sensitivity (B_1^- filed) due to chemical shift displacement. A localized spectrum may be weighed along a chemical shift direction by the weighting function determined by both of chemical shift displacement and B_1 profile. As a result, the magnitude of spectrum is modulated along the chemical shift direction. For example, magnitudes of NAA peak and Cr peak are weighed by the different values and this may lead to quantitation error. In this work, we will demonstrate this error in phantom experiments at 4.7 T. We will also demonstrate correction method using the profile of reception sensitivity measured by water signals.

Methods

All the measurements were performed on a 4.7 T whole-body MR system (INOVA, Agilent). We used a quadrature volume TEM coil of 300-mm diameter both for transmission and reception. We used a cylindrical phantom of 150-mm diameter filled with water. Three 50-ml bottles filled with mixture of 25 mM NAA and 25 mM Cr were placed vertically inside the phantom (Fig. 1).

To demonstrate quantitation error due to amplitude modulation along chemical shift direction

STEAM signals were acquired from the top, the center and the bottom voxels of 20 × 20 × 20 mm^3 inside these three bottles. Both RF power adjustments for localization and water suppression were done in all three voxels. TE was 4 ms and TR was 15 s. All 90° pulses were 2-ms asymmetric pulses (1) with bandwidth of 3375 Hz. Chemical shift displacement was around 1.2 mm per 1 ppm. While the carrier frequency in the STEAM sequence was tuned to 3.41 ppm, the shifted value from the center frequency is 1.4 ppm for NAA singlet at 2.01 ppm and that value is 0.39 ppm for Cr singlet at 3.02 ppm. While chemical shift displacement value is 1.7 mm for NAA and that is 0.5 mm for Cr, the displacement value between NAA and Cr is 1.2 mm. After obtaining spectra, we measured ratios of peak area of NAA to that of Cr in all three voxels.

To measure the profile of reception sensitivity and correct quantitation error

Next, we measured multiple water signals in each voxel by the STEAM sequence without water suppression with shifted carrier frequencies. Water peak areas represent reception sensitivities in the shifted voxels. The shifted values were -1.4, -0.7, 0, 0.7, 1.4, and 3.5 ppm away from the resonant frequency. These correspond to the slice displacement of -1.7, -0.8, 0, 0.8, 1.7, and 4.1 mm, respectively. A reciprocal of the measured profile of reception sensitivity was curve-fitted by a third polynomial expression in each voxel. After the measured STEAM spectrum was multiplied by the calculated curve in each voxel for correction, we measured a ratio of NAA to Cr in each corrected spectrum.

Results & Discussion

While a ratio of NAA to Cr is 2.6% higher in the bottom voxel than that in the center voxel, the ratio 4.0 % lower in the top voxel before correction (Fig. 2). Although the value of chemical shift displacement is only 1.2 mm, error of 6.6 % arose between the top and the bottom voxels. The ratios of all three voxels become closer after correction (Fig. 2). It means that a localized spectrum is weighted along a chemical shift direction by the profile of reception sensitivity. Since that sensitivity profile depends on the voxel position (Fig. 3), this caused quantitation errors in the ratio of NAA to Cr among three voxels.

Fig. 1. A schematic of the phantom (a) and the adiabatic spin echo image of the phantom (b).

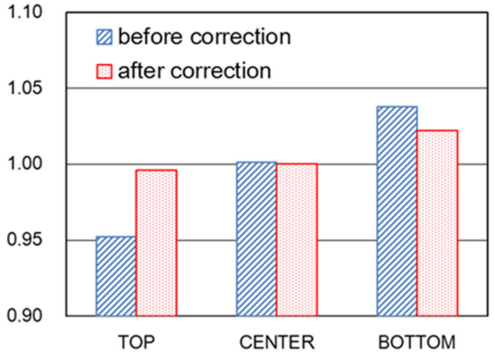

Fig. 2. Ratios of NAA to Cr in the top, center and bottom voxels before and after correction. Spectra were corrected using the profile of reception sensitivity measured by water signals.

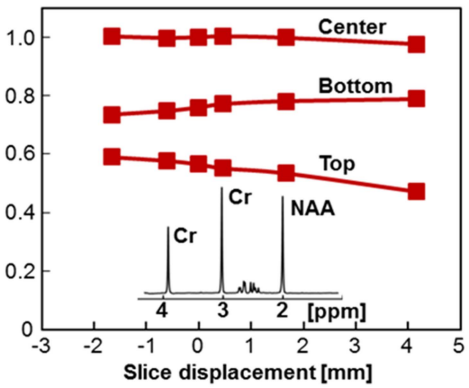

Fig. 3. Measured profiles of reception sensitivity in the top, center and bottom voxels. A localized spectrum of a mixture phantom of NAA and Cr in the center voxel is also shown considering the chemical shift displacement. A localized spectrum is weighted by the profile of the reception sensitivity in each voxel.

Conclusions

B_1 inhomogeneity and chemical shift displacement cause amplitude modulation along the chemical shift direction on a localized spectrum. This leads to quantitation error. This quantitation error may also occur by using surface coil for reception.

References

1. Tkáč I., Starcuk A, Choi IY, Gruetter R., *In vivo* ^{1}H NMR spectroscopy of rat brain at 1 ms echo time. Magn. Reson. Med. 1999;41(4):649-656.