An approach for absolute quantification of single voxel MR spectroscopy with receive-only head coils

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Introduction:

Absolute quantification of MR spectra requires signal calibration as well as correction for variable coil load and inhomogeneities of the local B1 field. Solutions for quantification that have been presented so far rely on the use of transmit-receive coils. In neuroradiology however, receive-only head coils are widely used. We therefore developed a method for the correction of differences in coil sensitivity (B1/I) and B1 field inhomogeneities of stimulated echo acquisition mode (STEAM) single voxel MR spectroscopy. This requires the aquisition of 10 additional spectra without water suppression (calibration spectra) with an total scan time of 60 seconds in vivo.

Material and Methods:

The pulse voltage (U_{RF}) provides an approach to determine B1/I. According to the principle of reciprocity the field distribution of the MR signal is identical to the transmitted B1 field distribution [1]. Consequently the local sensitivity is determined from the water signal of the voxel at different U_{RF}, fitted to the theoretical flip angle dependence [2]. This however is only valid for transmit-receive coils. Therefore the calibration spectra have to be measured using the body coil as transmitter and (I) head coil (II) body coil as receiver respectively (Fig.1). Due to the fact that the local sensitivity distributions are identical for the two coil systems and under consideration of the intensity quotient (S_{hb}) between them, the use of the reciprocity theorem becomes possible. The correct pulse voltage at the position of the voxel ($U_{90°local}$) can be determined from the maximum of the fitted signal ($S_{90°local}$). The corrected signal (S_{corr}) is calcuated as follows:

$$S_{corr} = \frac{U_{90°local}}{S_{hb}} \cdot \frac{S_{90°local}}{S_{90°global}} \cdot S_{spec},$$

where $S_{90°global}$ represents the water signal using autocalibrated U_{RF} and S_{spec} the raw signal of the spectrum.

MR protocol:

Short echo time spectra were acquired on a 1,5 T clinical MR unit (Symphony, Siemens, Erlangen, Germany) using a STEAM sequence (TE = 20 ms, TM = 10 ms). The protocol consisted of the measurement of (I) the actual spectrum (TR = 2000/4500 ms; n = 32/96 in vitro/in vivo), (II) a reference spectrum without water suppression for eddy current correction in vivo, and (III) 10 calibration spectra, 5 with each coil setup (TR = 1300/530 ms; n = 8 in vitro/in vivo). For the latter U_{RF} was manually adjusted (340, 390, 440, 490, 540 V), whereas autocalibration was used for the actual spectrum.

In vitro measurements:

In order to obtain different coil loads spherical water phantoms with different volumes (0,7 / 0,9 / 1,4 / 2,1 l) were placed at the center of the magnet. The voxel (V = 10,6 ml) was positioned at the isocenter. To investigate B1 field inhomogenities coil load was retained and the voxel position was changed by 35 mm in all directions (x,y,z,-x,-y,-z, respectively). The actual spectrum was measured without water suppression.

In vivo measurements:

In vivo, we assessed intraindividual variation without and with correction in a healthy volunteer, who was examined at four different points in time (day 0, 93, 93, 109). Each time an identical voxel of 8,4 ml was placed in the centrum semiovale. Metabolite concentrations were determined using LCModel software [3].

Results:

In vitro measurements:

The variation coefficient (v) of the water signal from different coil loads was 4,24 % without correction. After correction v was reduced to 0,22 % (Fig. 2). For different voxel positions v was 2,87 % without correction and 0,99 % with correction (Fig. 3). The variation coefficient for both measurements was 3,33 % without correction and 0,93 % after correction. The measurement reproducibility was v = 0,32 %.

In vivo measurements:

The intraindividual variations of the metabolites signals are shown in Table 1. Due to the correction method a relative reduction of v of 26 % (GPC), 41 % (Cr), 61 % (Water) and 71 % (NAA) was achieved.

Discussion:

The examined variations between the measurements are mainly based on differences in coil load and to a lower amount on B1 field inhomogenities. Both effects can be corrected, although not completely to the level of the measurement reproducibility. The correction is more efficient for differences in B1/I than for B1 field inhomogenites. In practise both effects are superimposed. The variations of the metabolites in vivo are not only based on these effects, but also on the LCModel analysis (standard deviations 4-9 %) and possible slightly changes of the voxel position bewteen the examinations. This accounts for the different residual variations after correction between in vitro and in vivo measurements. An important requirement for the described approach is an accurate tuned coil, as coil impedance has to be constant. Further investigations have to be done to investigate to which amount possible changes of coil impedance influenced our experiments. The described approach is applicable for clinical routine, as it is fast, user independent and the postprocessing can be added to an external quantification software like LCModel.

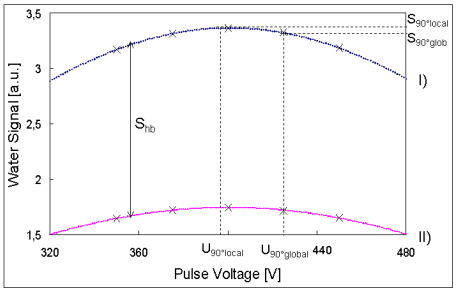

Fig.1: Sensitivity distribution for both coil setups: I) head coil as receiver, II) body coil as receiver

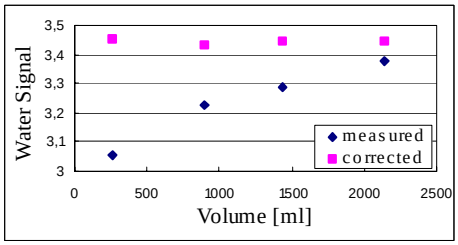

Fig.2: Water signal for different volumes

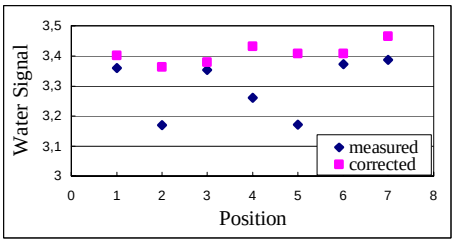

Fig.3: Water signal for different voxel positions

	Cr	NAA	GPC	Water
v (S_{spec})	10,5 %	4,2 %	6,1 %	5,2 %
v (S_{corr})	6,2 %	1,2 %	4,5 %	2,0 %

Table 1: variation coefficient of Cr (creatine), NAA (N-acetylaspartate), GPC (glycerophosphocholine) and water; measured v (S_{spec}) and corrected v (S_{corr}) signals

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