Comparison of Water Signal Decay and Image-Based Segmentation Techniques to Quantify MRS Voxel Composition

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Introduction

The concentration of brain metabolites varies between white matter, grey matter and CSF. For example, the concentration of the inhibitory neurotransmitter γ-aminobutyric acid (GABA) in CSF is approximately 500 pmol/ml [1], several orders of magnitude lower than its concentration in white or grey matter. The concentration of GABA has also been shown to be higher in grey matter than in white matter [2], in a single subject. Thus, knowledge of the fraction of each of the three components within the MRS voxel is important for absolute metabolite quantification of *in-vivo* ^{1}H MRS spectra. Historically, CSF estimation was achieved by a two-component fit to T_2-decay curve of the unsuppressed water spectrum [3], yielding the percentage contribution of CSF and 'brain water' (white + grey matter) to the signal. More recently, the segmentation and registration of a 3D structural image has been used, resulting in the fractional contribution of CSF, grey and white matter to the voxel. The purpose of this work was to investigate whether image-based segmentation and water signal decay methods produce equivalent results when applied to a group of recovered depressed patients and controls (where changes in the brain matter content and in GABA concentration have previously been reported [4]). This was achieved by (a) investigating the sensitivity of the two methods in estimating the fraction of an MRS voxel occupied by CSF, and, (b) evaluating the importance of accurately gauging the white-to-grey matter ratio within the MRS voxel, by measuring variation of GABA concentration with grey matter across both subject groups.

Methods

Eight healthy controls and fourteen recovered-depressed (RD) patients who were euthymic and medication free for a period of at least 3 months and who suffered with an affective illness in the past, were studied using a Varian INOVA 3 Tesla whole-body system. Water T_2-decay and T_1-weighted structural image data were acquired during the same session, without repositioning the subject. Water decay measurements were taken with PRESS localisation of a 30x30x20mm voxel centred on the occipital lobe. Unsuppressed water spectra were collected at a range of echo times from 26ms to 1.2s and analysed using *VARPRO* [5], with the resulting T_2-decay curves fitted with two components whose amplitudes and time-constants were allowed to vary. Segmentation was performed using *FSL FAST* [6]. The data were analysed with both 'hard' segmentation (in which each pixel is assigned as either white matter, grey matter, or CSF only) or 'partial volume' segmentation (PVS), where the output is the most likely fraction of white matter, grey matter and CSF in any given pixel in the segmented image. For quantifying the dependence of the GABA concentration with the grey matter%, GABA-edited spectra were acquired using a MEGA-PRESS sequence [7] at TE=68ms to edit the GABA resonance at 3.0ppm. Standard PRESS metabolite spectra were acquired at echo times TE=26ms and TE=68ms, to quantify Creatine (Cr) concentration, as a reference.

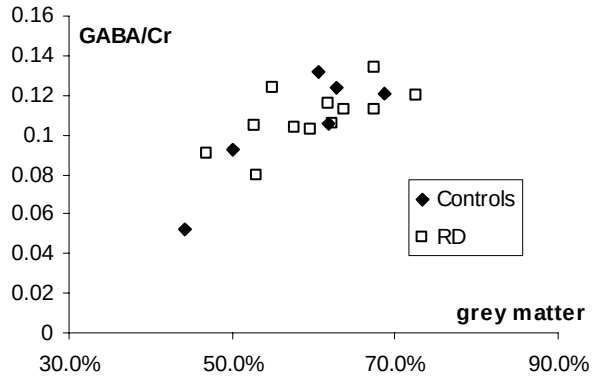
Results

The two-component fit of the water decay data yielded highly reproducible values for the T_2 of the 'brain water' component across the whole subject group (63.7 ± 1.9 ms). Table 1 shows a summary of the measurement of CSF fraction within the voxel, as a percentage of the total voxel volume. There is good agreement in the control group's mean CSF% for the PVS and water decay measurements. The segmentation results do not show a significant difference in the mean of the CSF% between the control and RD subject groups (for PVS, p=0.62). However, the difference between the groups is significant when analysed using the water decay measurement (p<0.05). The data showing the variation in the GABA:Cr ratio with grey matter for both groups are shown in Figure 1. The grey matter is expressed as a percentage of the total brain matter within the voxel (these data are a subset of the groups in Table 1, with $N_{controls}$=6, N_{RD}=12). Analysis of GABA:Cr with diagnosis group as a factor and the grey matter% as a covariate show a significant (p< 0.01) effect with grey matter%, but no significant trend with group.

Table 1: CSF% present within MRS voxel (mean ± sd)

	N	Segmentation		Water Decay
		Hard	PVS	
Controls	8	8.2 ± 4.3	6.6 ± 3.7	6.5 ± 1.7
RD	14	10.3 ± 7.3	7.5 ± 5.0	9.3 ± 3.8

Figure 1: GABA:Cr as a function of grey matter%



Discussion

The water decay measurement of CSF% showing a significant difference between the groups is consistent with Sanacora *et al* [4]. The lower variance of the water decay measurements compared with the PVS measurements is a contributory factor to this result. It also appears that hard segmentation tends to systematically overestimate the CSF% in both groups. Segmentation does yield information about the white and grey matter content of the voxel which is not available with water decay alone; Figure 1 shows that the grey matter% in the MRS voxel has a significant effect on the GABA:Cr ratio across a range of subjects, consistent with the findings of Choi *et al* [2]. The additional information obtained through segmentation leads to the removal of one of the potential confounds in MRS quantification; the variation in metabolite concentration between white and grey matter. However, it should be noted that the water decay method appears to be a more sensitive method for detecting subtle CSF% changes between subject groups.

References: [1] Nisijima and Ishiguro, *J, Psychiat. Res.*,29, 233, 1995 [2] Choi *et. al. Proc ISMRM* 11, 109, 2004 [3] Ernst T *et. al., J Magn Res B* 102, 1, 1993 [4] Sanacora *et. al. Arch. Gen. Psych.* 61, 712 , 2004 [5] A. Knijn, *et. al., J. Magn. Reson.* 97, 444, 1992 [6] Zhang *et al. IEEE Trans. on Medical Imaging*, 20, 45, 2001 [7] Mescher *et. al. NMR Biomed* 11, 266, 1998.