Multicomponent T2 analysis of rat brain and spinal cord at 9.4 T

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INTRODUCTION

T2 relaxation time varies with many pathophysiological conditions such as stroke, muscular dystrophy and MS plaque development. The value is influenced by a combination of factors such as water content, myelin content and subtle changes in the biochemical makeup of the cells. Since it is sensitive to disease progression, it may be possible to evaluate treatments by monitoring changes in T2. Since it has been noted that brain T2 values are likely to be multi-exponential, but only a limited number of groups are reporting multi-exponential fitting routines, we assessed the variation in T2 that is caused by different analysis between single and multi-exponential fitting. This study compares single and multi-exponential analyses to quantify T2 in normal rat brain and spinal cord at 9.4 T. We applied non-negative least squares fitting to triple, double, and single exponential functions as well as fitting to an unspecified number of exponential functions to the same image sets.

METHODS

Male Wistar rats were imaged at 9.4 T using a Bruker console and 35 or 45 mm quadrature birdcage coils. Multi-echo spin echo images of the brain and spinal cord were acquired while rats were anesthetized with isoflurane (TR=1.5 s, TE=3 ms, 128 echoes, matrix size=128x128 pixels, slice thickness=1.5 mm, NEX=4, Gauss refocusing pulses). Signal decay curves from regions of interest were analyzed using single or multi-exponential functions to determine *in vivo* T2 values. SigmaPlot 9.0 (Systat Software Inc.) was used to fit the decay curves to single, double and triple exponential functions. Multi-exponential analysis (MEA) was done using non-negative least squares function in MATLAB 6.5 (The Mathworks Inc.) with 400 iterations and a spectral limit of 1700 ms. The first two echoes were excluded from analyses. Signal values below 3 standard deviations (StD) of the noise also were excluded. The noise level and StD were measured from a ROI in the background region outside the rat.

RESULTS

Table 1 shows the T2 values of brain and spinal cord regions using single, bi-exponential (SigmaPlot) and multi-exponential (MatLab) analyses. Our values of S/N were in the range of 100-230. The results for the triple exponential model are not presented because all the brain regions and 10 out of 21 spinal cord regions had two identical T2 values. This indicates that a bi-exponential fit was more appropriate. Furthermore, the triple exponential model did not converge in 4 of the spinal cord regions. Using MEA analysis, two T2 values were found in all brain regions and most of the spinal cord regions. However, a third T2 component was found in three spinal cord white matter regions (183, 89, and 85 ms) and one spinal cord grey matter region (196 ms).

Table 1. T2 values (mean ± StD) at 9.4T from rat brain (n=6) and spinal cord (n=7) regions. Fractional areas of each component of the bi-exponential model are shown in parentheses.

Analysis Method	**Brain T2 (ms)**						**Spinal Cord T2 (ms)**					
	Whole brain		**Cortex**		**Corpus Collosum**		**Whole spine**		**Grey matter**		**White matter**	
Single exponential	50.0 ± 1.8		48.8±1.8		43.2±2.4		45.4±0.7		43.6±1.3		50.2±1.0	
Bi-exponential	36±9 (40±29)	66±15 (60±29)	28±15 (19±22)	52±5 (81±29)	26±15 (33±36)	52±15 (78±33)	14±1 (6±2)	49±1 (94±1)	6±3 (2±1)	44±1 (98±1)	16±4 (13±4)	62±5 (87±4)
MEA	35±11	64±15	36±9	60±8	35±7	78±38	29±5	64±3	27±9	60±20	25±9	67±22

DISCUSSION

Our T2 results from bi-exponential fit and MEA are similar for brain regions. However, T2 values from spinal cord regions are lower when determined using a bi-exponential model compared to MEA. Paradoxically, the spinal cord white matter T2 was greater that the spinal cord grey matter T2 and corpus collosum T2. This may be related to partial volume effects of adjacent cerebral spinal fluid. The single exponential T2 value of rat brain at 9.4 T including the corpus collosum and cortex was previously reported to be 42 ms [1], which is similar to the single exponential value we found for the corpus collosum. Other groups using bi-exponential fitting have found T2 values of 64 and 184 ms for brain grey matter [2] and 8.3 and 37.7 ms for brain white matter [3]. Dula and Does also reported a single exponential value for rat brain grey matter of 40.4 ms. The T2 values reported by [2] are different from our T2 values and may be because they constrained the T2 values to be between 20 and 450 ms. Using *a priori* knowledge may help improve the precision of the determination of T2 in brain. When attempting to detect small changes (a few ms) between groups, it is unlikely that MEA will be successful. The MEA routine appears useful if the number of T2 values is uncertain. Single and bi-exponential fittings are likely to be more sensitive to very small changes in T2.

REFERENCES

1. Lei, H. et al., *Magn. Res. Med.*49, 979-984, 2003.
2. Lascialfari, A., et al., *Magn. Res. Med.*53, 1326-1332, 2005.
3. Dula, A., and M. Does *ISMRM abstract,* 2005.