Quantification of Multicomponent T2 in Brain After Reversible Ischemia

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INTRODUCTION

Multi-echo T2 acquisitions, in combination with a multi-exponential analysis function, have been used effectively to study a range of neurological disorders—in particular multiple sclerosis [1]. Such quantification has provided novel insights into brain microstructure and disease progression [2]. In this study, we applied similar methods to study tissue degeneration in a reversible stroke model. We hypothesized that multi-exponential T2 analysis would provide additional information about the infarct over that of a single exponential analysis.

METHODS

Infarcts were induced using a clip model with one hour of reversible middle cerebral artery occlusion [3]. MR imaging on male Wistar rats (n=5) was conducted at 9.4T using a Bruker console and a 35 or 45mm quadrature birdcage coil 1 day after transient ischemia. A multi-echo spin echo sequence was used to quantify T2 *in vivo* (TR=1.5s, TE=3ms, 128 echoes, FOV=3x3 cm, matrix=128x128 pixels, slice=1.5 mm, NT=4). Multiexponential analysis was done using AnalyzeNNLS [4], which uses matlabs non-negative least squares fitting routine. The fitting was constrained from 5-330ms and began at the third echo (9ms). Single exponential analysis was done using sigmaplot, with a 3 parameter fitting routine.

RESULTS

Figure 1 shows an example infarct in T2w MRI. A characteristic hyperintensity covers much of the cortex and overlaps parts of the internal capsule white matter tracks (arrow). The cortex region of interest (ROI) was located in the centre of such a region while the white matter ROI was placed over hyperintense regions of the internal capsule. Using multiexponential analysis, two relaxation components were observed in each region (termed T2a and T2b). The T2 values increased with stroke as per all analysis methods (Table 1). The change in T2 in white matter with single exponential analysis was much less than that of each individual component. The shorter component (T2a) showed large increases in relative proportion in gray and white matter (Table 2). These changes in T2 and proportion are easily seen in an example T2 distribution from the gray matter of one rat (Fig. 2). The average proportions of T2a increased by approximately 10x in the cortical stroke region.

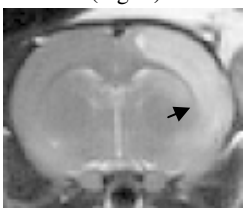

Figure 1: T2w MRI of a representative stroke region showing hyperintense region of cortex and part of internal capsule (arrow). Imaging was done 24 hrs after 1hr reversible ischemia.

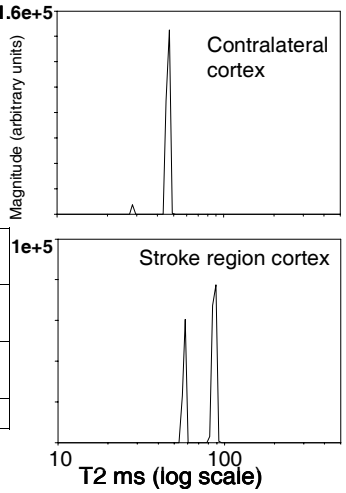

Figure 2: Example T2 distribution from one animal. Note the large increase in proportion of the short component and the general shift in T2 to longer values.

Table 1: T2 relaxation times (ms) for regions of gray and white matter in normal brain, and brain after stroke (mean±SD, n=5). *indicates significant difference from control ($p<0.05$).

	Cortex		White Matter Internal capsule	
	Contralateral normal	Stroke region	Contralateral normal	Stroke Region
T2a	23.1±8.1	51.6±7.2*	25.7±9.2	34.1±9.3
T2b	46.6±0.7	85.0±4.6*	45.0±2.4	61.6±11.0*
T2 single	45.8±0.7	74.9±3.5*	42.4±0.6	46.5±1.9

Table 2: Fractional area of each relaxation component (mean±SD, n=5). *indicates significant difference from control ($p<0.05$).

	Cortex		White Matter Internal capsule	
	Contralateral normal	Stroke region	Contralateral normal	Stroke Region
Area T2a	0.028±0.016	0.305±0.103*	0.139±0.144	0.457±0.287*
Area T2b	0.972±0.016	0.695±0.103*	0.856±0.145	0.531±0.287*

DISCUSSION

The increase in T2 of the stroke, 24 hrs after ischemia, has been previously observed [5]. The multicomponent analysis provided additional information over that of a single exponential. This is because the fractional contribution of the two relaxation components changed in stroke. One explanation is that the short component increased in proportion by 10x in the grey matter and 3x in white matter. Consequently, the single exponential function showed less relative change in T2, especially in white matter. Another, more novel explanation, is that a new component with a longer relaxation time appears after stroke and that the T2b in normal brain corresponds to the T2a in the stroke region. This change in proportions of the components is clearly providing novel information, although much more validation will be required to interpret the change. The short component is unlikely to be short enough to represent the myelin fraction, as has been suggested in human studies [1,2] and there is no anatomical reason to argue for an increase in myelin fraction in this model.

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