Multi-spectral Analysis of Relaxation Time Maps on Fetal Baboon Brains

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INTRODUCTION

Relaxation times are sensitive to the continuous and rapid changes in the structural organization and water content of both gray matter and white matter during early life. Sequential *in utero* measurement of T_1 and T_2 can be used in characterization of the earliest stages of longitudinal development of brain tissues [1]. We used both relaxation times in different tissue environments to extract the multi-spectral maps [2] as a quantitative diagnostic tool for differentiation of immature brain tissues. Additional sensitivity is achieved since in practice the MR signal is affected by both relaxation mechanisms of the protons present in different environments simultaneously.

METHODS

Pregnant baboons have been successfully scanned sequentially across pregnancy, with acquisition of MRI images of fetal brains at gestational ages (GA) ranging from 64 to 185 dg [1]. Relaxometry pulse sequences were implemented on GE Signa 3T Excite Scanner (GE Medical System, WI) with a GE quadrature head coil. Pregnant baboon with fetus of up to term of about 185 days of gestation (dg) could comfortably fit in the coil even after being wrapped with a blanket. For scanning, the animal was kept anesthetized and mechanically ventilated. For comparison, one baboon was scanned sequentially after birth.

Fast Spin Echo (FSE) was used for all T_1 andT_2 relaxometry measurements: FOV = 12 cm, matrix size = 128 x 128, slice thickness = 3 mm, slice spacing = 0 mm, NEX = 1, echo train length (ETL) = 32. For T_2 relaxometry measurement by FSE, the images were acquired at effective TEs of around 10, 35, 70, 105, 140, 175, 210, and 245 ms, with TR = 3500 ms. For T_1 relaxometry measurement by IR-FSE, the images were acquired at TIs of 60, 300, 750, 1500, and 3000 ms, with TR = 10000 ms and Minimum TE. Curve-fitting these series of images using mono-exponential model on pixel-by-pixel basis gave the T_2 and T_1 relaxometry maps.

We then used T_1 and T_2 maps of the same baboon at the same GA to obtain a 2-D histogram of the maps (multi-spectrum). In the 2-D histogram, we chose T_1 and T_2 regions which covered most of the voxels. Then, the T_1 and T_2 regions were divided evenly into small bins and therefore the 2-D region in the histogram was divided into uniform 2D boxes. We assigned each box a different color, and then used this color to mark all the voxels with T_1 and T_2 values falling within this box.

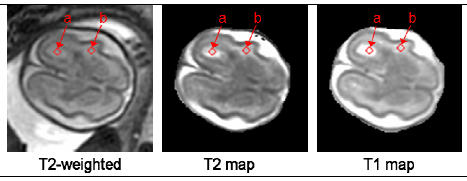

Figure 1. Intensities in CSF (a) and WM (b). Left: in T_2-weighted images (TE=175), I_a/I_b = (783±31) / (800 ±23); Middle: in T_2 map, I_a/I_b = (344±21) / (288±12); Right: in T_1 map, I_a/I_b = (2699±153) / (2133±96). Maps have better overall contrast.

RESULTS AND DISCUSSIONS

Either T_1 map or T_2 map can provide better contrast than the simple T1W or T2W images (Fig. 1). Nevertheless, multi-spectral analysis of the T_1 and T_2 maps can reveal more details on the brain development (Fig.2). The 2-D griding is built based on the relaxation values of various tissues during the brain development. Due to the changing nature of these tissues their relaxation values changes with gestation age (GA). Different regions in brain maps show different colors (different T_1 and T_2 combinations). The color-coded map may reveal the relationship between different regions in brain or show the developmental trajectory in different regions if we repeat this analysis method at different GAs. Figure 2a shows colored multiple layers around ventricle (in the green box). Figure 2b shows that two small regions have similar T_2 values (indistinguishable in both Fig. 2a and 2b), but different T_1 values (distinguishable in Fig. 2b, not in Fig. 2a). Since fetal brains develop fast, the T_1 and T_2 values change at different GAs. Fixed 2-D griding rules might not work well for all the GAs. How to divide the T_1 and T_2 determines how different brain regions can be viewed and segmented. Sometimes, more information can be obtained by combining different segmentations from different T_1 and T2 divisions.

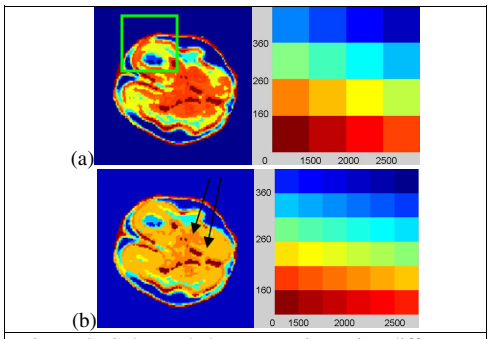

Figure 2. Color-coded segmentation using different T_1 and T_2 divisions. (a) In the green-box ROI, multiple layers are distinguishable; (b) Different regions (arrows) show similar T_2 values, but different T_1 values.

The 2-D histogram at different GAs shows the trend of T_1 of T_2 in developing fetal brain (Fig. 3). The difference in T_2 (or T_1) of different brain regions is large at earlier GA; this difference disappears at term, which makes the brain segmentation extremely hard.

We also used this color-coding technique on the postnatal brain (Fig.4). The change of the color shows the development in the regions, such as white matter and thalamus. In the postnatal brain, T_2 difference in different ROIs is less than T_1 difference. Therefore, T_1 map is more useful for segmentation, and we divided the T_1 region into more boxes in order to detect more detailed changes in different regions.

REFERENCES

[1] Liu, et al. ISMRM 2007;15:2348. [2] Alfano, et al. JMRI 2000;12:799.

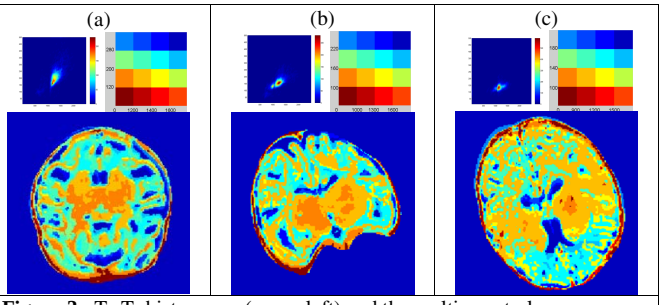

Figure 3. T_1-T_2 histograms (upper left) and the multi-spectral maps (lower) at different GAs: (a) 141 dg; (b) 162 dg; (c) 185 dg.

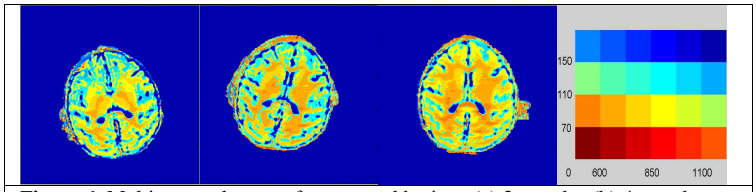

Figure 4. Multi-spectral maps of a postnatal brain at (a) 3 months, (b) 4 months and (c) 5 months. Both T_1 and T_2 of most brain tissues tend to decrease as the brain matures.