Investigation of White Matter Characteristics using Interslice Magnetization Transfer Ratio and Asymmetry at High Field

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Introduction

Imaging myelin is important for studies related to white matter diseases. There are various MRI methods for imaging myelin-related structures such as myelin-water imaging (1), quantitative susceptibility mapping, and magnetization transfer imaging, but the signal to noise ratio and specificity to myelin have been the main obstacles. Magnetization transfer imaging has shown good white matter contrast and relatively high sensitivity, and thus may be a good choice for studying myelination. Alternate Ascending/Descending Directional Navigation (ALADDIN) is a new method for imaging perfusion-weighted (2) and magnetization transfer asymmetry (MT Asym.) (3). ALADDIN uses a different approach from conventional magnetization transfer imaging in that interslice MT effects are used for MT contrast and no separate MT pulse is applied (3). By additionally acquiring MT free images with a long interslice delay time, we can also generate MT ratio images from ALADDIN acquisition (4). The MT asymmetry and MT ratio images acquired by ALADDIN may provide new insights into white matter characteristics. In this study, we applied for the ALADDIN method on rat brains at 9.4T and investigated MT-related signals in different tissue regions at various flip angles.

Material and Methods

Experiments were performed on a 9.4T animal MRI system. A rat was studied after anesthetized by isofluorane mixed with air composed of pure oxygen and nitrous oxide with ratio of 3:7. ALADDIN acquisition was repeated at different flip angles of 30°, 45°, and 60°. Imaging parameters were TR/TE = 3.8/1.9 ms, matrix = 128×128, FOV = 30×30 mm^2, the number of slices = 20 or 21, thickness = 1 mm, gap = 1 mm. Additionally, MT free (S0) images were acquired for MT ratio images ($=(S_0-S_{MT})/S_0$) where S_0 and S_{MT} represent MT freee and MT-weighted images). For MT free imaging, interslice delay was set at 6 sec. Scan time was 13.6 min for ALADDIN MT weighted images and 2.2 min for MT free images. Regions of interest (ROIs) indicating WM, GM, and muscle were manually defined using MATLAB.

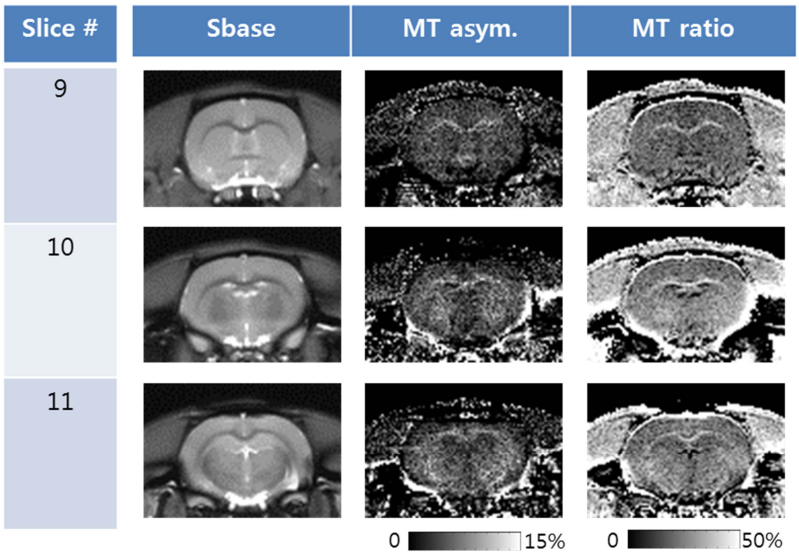

Fig. 1. Three middle slices of baseline (Sbase), MT asymmetry (MT Asym.), and MT ratio images. Flip angle = 60°, scan time = 15.7 min.

Results and Discussion

Figure 1 displays baseline, MT asymmetry, and MT ratio images of the 3 middle slices acquired at flip angle of 60°. MT ratio images (right column in Fig. 1) show clear white matter (WM) contrast, although signals in gray matter (GM) and muscle were not negligible. MT asymmetry images also show brighter signals in WM, but show much lower signals in GM and muscle, in contrast to MT ratio images. Also, the brighter regions in MT asymmetry images were slightly different from those in MT ratio images in that the subcortical regions also showed brighter signals comparable to WM in the cortical regions. These observations were consistent with the ROI analysis shown in Fig. 2. WM signals were more than twice the signals in GM and muscle in MT asymmetry images, whereas signals in GM / muscle were compared those in WM in case of MT ratio images (Fig. 2). Overall, both MT asymmetry and MT ratio increased with flip angle for all the tissue regions, implying the sensitivity could be further improved.

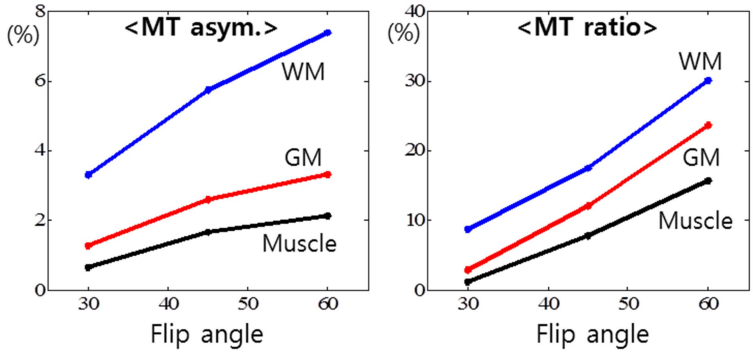

Fig. 2. Region of interest analysis for MT asymmetry and MT ratio in gray matter (GM), white matter (WM), and muscle.

These results indicate that MT asymmetry may has specificity to myelin and that combination of MT asymmetry and MT ratio may be a promising tool for better understanding of characteristics of WM. Inhomogeneous MT effects of myelin have been suggested for myelin imaging recently (5,6). Both the MT asymmetry and the inhomogeneous MT techniques take advantage of the fact that water spectrum distribution of myelin is not symmetric or homogeneous around the water resonance frequency. Further studies are necessary to compare the proposed MT asymmetry with other myelin imaging (e.g. inhomogeneous MT) and to understand and validate the signal sources by histology studies or imaging studies with demyelinated animals.

References

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