Introduction

Multi-parametric (ADC, T1 and T2) MRI has been used to monitor tumor progression and treatment response, yet unambiguous demarcation of tumor from peritumoral edema is often difficult due to diffuse tumor boundary [1-2]. Given that both T1 and T2 of tumor and edema alter to different extent, we here postulated that a T1/T2 ratio (i.e., T1/T2) could be useful in delineating tumor from surrounding edematous and normal brain tissues. The aim of our study was to compare T1/T2 map with commonly used multi-parametric MRI for demarcating tumor.

Materials and Methods

Brain Glioma Model: 2x105 rat glioma (D74/HveC) cells were implanted intracranially in male Fischer 344 rats (160-230 g; N = 5). Tumors were grown for 11 days prior to MRI. Left femoral vein was cannulated for contrast agent injection.

Multi-parametric MRI: MRI experiments were performed on a 4.7T Bruker MRI scanner. Each animal was anesthetized, with heart rate and blood pO2 monitored online. In addition, body temperature was maintained within the normal physiological range. Multislice MRI (5 slices, slice thickness/gap = 1.8/0.2 mm, field of view = 25x25 mm2, acquisition matrix = 64x64) was obtained with single-shot echo-planar imaging (EPI) (receiver bandwidth = 200 kHz).

In addition to the T1, T2 and ADC maps, a T1/T2 ratio map was obtained using an inversion recovery sequence, with seven inversion delays from 250 ms to 3000 ms (TR/TE = 6500/14.8 ms, NA = 4); T1 images were obtained with two TE of 30 and 100 ms (TR = 3250 ms, NA = 16). T1 images were acquired using an inversion recovery sequence, with seven inversion delays from 250 ms to 3000 ms (TR/TE = 6500/14.8 ms, NA = 4); T1 images were obtained with two TE of 30 and 100 ms (TR = 3250 ms, NA = 16). In addition, contrast-enhanced T1W FLASH images (acquisition matrix = 128x128, TR/TE = 100/5.5 ms, FA = 30°, NA = 4) were acquired after injection of gadolinium (Gd-BOPTA, -0.2 mmol/kg) for visualizing contrast-enhanced tumor lesion.

Image and Data Analysis: ADC, T1 and T2 maps were obtained by least-square fitting of the signal intensities as a function of b-value, inversion time and echo time, respectively. T1/T2 ratio maps were computed by pixel-by-pixel. Region of interest (ROI) analysis was performed in one slice with considerable peritumoral edematous and tumor tissues in each animal. Specifically, ROIs were defined on Gd enhanced T1W images for tumor lesion, and on ADC maps for peritumoral edematous tissue based on prolonged ADC compared to normal brain tissue, with care of excluding cerebrospinal fluid (CSF) and the defined tumor ROIs.

Results and Discussions

Fig. 1 shows ADC, T1, T2 and T1/T2 maps in addition to Gd-enhanced T1W images from a representative animal. For rat D74/HveC glioma tumor, we found it difficult to use ADC and T1 maps to demarcate tumor from peritumoral edema, while T2 showed very little contrast. In comparison, T1/T2 map was able to suppress contrast from peritumoral edema, thus better delineate tumor lesion from surrounding tissues. Noteworthy, ADC, T1 and T2 showed hyperintensity in the third slice, while neither T1/T2 nor Gd-enhanced MRI showed abnormality. Therefore, it appears that T1/T2 provides more specific characterization of tumor in addition, T1/T2 ratio map exhibited low contrast for CSF, which has both high ADC and relaxation times, allowing differentiation of these pathologic structures. Most importantly, the delineation of tumor in the high contrast T1/T2 ratio maps well corresponded to the Gd contrast-enhanced tumor lesion, suggesting its capability to demarcate tumor tissue from surrounding tissues without injection of contrast agent. Similar to other parametric maps, spatial heterogeneity could be observed within the tumor tissue in the T1/T2 ratio map, likely reflecting varying local pathophysiological properties such as cellularity of the tumor microenvironment.

Fig. 2 compares ADC, T1, T2 and T1/T2 ratio of tumor and peritumoral edematous tissues. Note that measurements of MRI parameters over the tumor ROI only reflected the average values of entire tumor, which is often heterogeneous. It shows that T1/T2 ratio provided the best contrast between tumor and edema. The percentage differences of parameters between tumor and edematous tissue with tumor as reference (i.e., |Tumor - Edema| / Tumor) were 6.6%, 9.4%, -12.7% and 19.9% for ADC, T1, T2 and T1/T2 ratio, respectively. It is interesting to note that T1/T2 ratio has been explored in discriminating hepatocellular carcinomas and metastases from benign hepatic lesions such as cysts and hemangiomas in a previous viver study [3], indicating distinct T1/T2 relaxation behavior in different pathologic structures. Further evaluation of T1/T2 ratio mapping in demarcating tumor from surrounding tissues is warranted in future studies with different brain tumor types.

Discussion

Multi-parametric (ADC, T1 and T2) MRI has been used to monitor tumor progression and treatment response, yet unambiguous demarcation of tumor from peritumoral edema is often difficult due to diffuse tumor boundary [1-2]. Given that both T1 and T2 of tumor and edema alter to different extent, we here postulated that a T1/T2 ratio (i.e., T1/T2) could be useful in delineating tumor from surrounding edematous and normal brain tissues. The aim of our study was to compare T1/T2 map with commonly used multi-parametric MRI for demarcating tumor.

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Conclusion

This study, T1/T2 ratio mapping was compared with commonly used multi-parametric MRI in characterizing rat glioma tumor. Our data showed that T1/T2 better depicted brain tumor region by suppressing signal from peritumoral edema and CSF, which typically show similar contrast to brain tumor lesion in conventional MRI parameter maps. Moreover, the delineation of tumor tissue in T1/T2 ratio map was in good agreement with that of Gd contrast-enhanced T1W MRI. Given that T1 and T2 are widely used diagnostic imaging methods, the proposed T1/T2 mapping can be easily translated to clinics, which may assist differential diagnosis and treatment planning of brain tumors in clinical settings.

References