Oligodendroglioma Characterization with Diffusion Weighted Imaging and Chemical Shift Imaging

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Introduction Recently the microenvironment of normal and tumor tissues have been increasingly assessed non-invasively with magnetic resonance imaging (MRI) methods, such as, diffusion weighted imaging (DWI) and chemical shift imaging (CSI). DWI allows the possibility of evaluating the random motion of water molecules in apparent diffusivity and its spatial anisotropy inside various biological tissues, such as myelinated white matter and muscular tissue. CSI, however, allows a direct assessment of pathological tissue in term of biochemistry, providing comprehensive and specific information regarding to a pathological tissue. From the resulting localized MR spectra from brain, a number of metabolites including NAA, choline, creatine, lactate, and etc can be detected and their concentrations can be estimated, which can be used to characterize and classify a unknown lesion. The main aim of this study was to investigate oligodendrogliomas non-invasively with both DTI and CSI. And, the other aim is to investigate if there is an underlying relationship between choline concentration and ADC of lesion tissue.

Materials and Methods All MR imaging results shown in the abstract were obtained with a Philips 1.5T clinical MR scanner ACS-NT PowerTrack 6000 (Best, The Netherlands). This particular MRI machine was equipped with a self-shielded gradient coil set with maximum gradient field strength of 23 mT/m and maximum slew rate of 105mT/m/ms. A Philips receive-only birdcage head coil was used in the MR study. All patients were scanned in supine and head first position. As part of the comprehensive MR examination, both DTI and CSI acquisitions were performed in a single session without moving the patient. The DTI technique used in the study was a single-shot diffusion weighted imaging acquisition performed with an echo planar imaging (EPI) scheme, whose sequence was based on the spin-echo EPI with an echo train length (ETL) of 64. Other MR imaging parameters for the DTI acquisition were: 64x64 raw data matrix at a field of view (FOV) of 210mm with a thickness of 7mm. The sequence repetition time (TR) was 4000-5000msec with an effective echo time (TE) of 123 msec. 15-17 imaging slices were obtained in an interleaved fashion with a gap of 1mm in axial orientation covering the entire patient brain. A diffusion gradient encoding pulse were applied in six non-colinear directions (b= 1000s/mm^2). The resulting DTI images (NSA=2) were analyzed off-line on a Unix workstation using software programs. The CSI technique employed in the study was based on an efficient spectroscopic imaging scheme using three consecutive spin echoes (TR/TE=2000/272msec, ETL=3). The matrix sizes of the CSI data acquisition were 32x32 in time domain. The field of view of CSI acquisition was 210mm and the slice thickness was 15-20mm. In a typical study, we obtained either one or two CSI slices depending on the tumor volume. The total scan time was 11 min for the CSI scan with circular k-space coverage. The spectroscopic images of various brain metabolites of interests were obtained through numerical integration of their corresponding peaks in the spectral domain. The normalized choline ratio of the lesion was calculated from the resulting spectroscopic images as follows: [choline intensity of lesion] / [choline intensity of reference tissue].

Results Seven brain tumor patients (age: 42.1+/-8.5 yo), who were diagnosed with oligodendrogliomas within 8.0 +/- 6.9 days by prospective MR guided brain biopsy or resection, were involved in the study. The typical images of choline, ADC, and FA of oligodendroglioma are displayed below. Due to the disease process, the mean ADC of the tumor tissue (1.63+/-0.39 x10^{-3} mm^2/s) exhibited a statistically significant increase (84%, $p < 0.00047$) relative to normal brain (0.88+/-0.21 x10^{-3} mm^2/s) on the contralateral side while the corresponding FA value (0.088+/-0.021) showed a dramatical reduction (74%, $p<0.00076$) in the affected WM areas in comparison with the value (0.36+/-0.13) measured from the reference area. A histogram analysis shows the distribution of the FA of oligodendroglioma in comparison with the normal brain tissue measured at the contralateral side. Quantitatively, the lesion tissue is generally characterized by a narrow distribution in FA values centered at 0.097 with a half width of 0.046, while the normal brain area by a much broader distribution centered at 0.32 with a half width of 0.23. The choline ratio was obtained from the choline image reconstructed from the CSI data. The averaged choline signal intensity of the lesions studied was 1.92+/-0.71 times of that of the normal brain. Though the choline level of this particular type low grade gliomas did appear to vary over a significantly wide range as indicated by the large standard deviation, the choline level was found to be linearly related to the ADC of the lesion with a negative slope: ADC [x10^{-3}mm^2/s] = 2.46-0.43 rCho, $R^2 = 0.6314$, where rCho = [Tumor Choline] / [normal Choline].

Conclusions A quantitative characterization of oligodendroglioma was done in terms of water diffusion and neurochemistry. Typical oligodendroglioma tissues exhibit elevated mean ADC and choline ratio, diminished FA values and NAA ratio. Although there is a broad spread in these parameters, the choline ratio was found to be linearly correlated with ADC with negative slope. This result further supports the notion that ADC might provide another MR based measurement of cellularity, which can be particularly useful in making quantitative clinical diagnosis.