Diffusion Tensor Imaging and Pathologic Correlates of Meningiomas

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TARGET AUDIENCE

Neuroradiologists, Neuropathologists, Neurooncologists, Neurosurgeons, Researchers

PURPOSE

The extent of tumor resection and histologic grade are key determinants of clinical outcome and recurrence in patients with meningiomas. In skull base meningiomas, where the tumor is intimately attached to cranial nerves and major arteries, one major determinant for extent of resection is tumor consistency. Hard consistency, as encountered in fibroblastic subtypes, makes complete resection extremely difficult or impossible. The high content of intercellular collagen, a fibrous protein, is believed to be responsible for the hard consistency of meningiomas. Ki-67, a cell proliferation marker, has been shown to correlate with histologic grade and used to predict recurrence and patient survival in meningiomas[1]. Previous DTI studies reported that fibroblastic meningiomas had higher FA and CP compared with other subtypes[2-5]. Atypical meningiomas had lower MD values compared with typical meningiomas[2,6]. However, there is no report on the correlation of DTI and histologic findings. The purpose of this study was to correlate DTI metrics with the histologic findings including collagen content and Ki-67 labeling index in meningiomas.

METHODS

Forty-five meningiomas with histopathologic diagnosis of atypical (n=8, Grade II, 7M/1F, age 47-80), anaplastic (n=2, Grade III, 2F, age 44-56) and typical (n=35, Grade I, 8M/27F, age 27-86) meningiomas were included. Subtypes of typical meningiomas included 10 fibroblastic, 7 transitional, 17 meningothelial and 1 angiomatous. Atypical and anaplastic meningiomas were grouped together as atypical meningiomas. Of the typical meningiomas, meningothelial and angiomatous subtypes were grouped together as "others". All patients underwent MR studies before surgery on a 3T Siemens Tim Trio scanner with a 12-channel phased-array head coil. DTI data was acquired using a single shot spin echo EPI sequence with parallel imaging using GRAPPA (acceleration factor = 2). Sequence parameters were as follows: TR/TE = 5000/86, NEX = 3, FOV = 22 x 22 cm^2, b = 1000 s/mm^2, number of diffusion weighting directions = 30, slice thickness 3 mm. Contrast-enhanced T1 weighted images, FLAIR, and DTI metrics including fractional anisotropy (FA), mean diffusivity (MD), linear anisotropy (CL), planar anisotropy (CP) and spherical anisotropy (CS) maps were co-registered and the median values were computed from the enhancing region. After the surgery, the histologic slides from the patients were evaluated for collagen content and Ki-67. Sirius Red was used for collagen stain. The percentage of collagen content was calculated using the following equation: Collagen content (%) = (collagen area/total tumor area) × 100. Immunohistochemical staining for the Ki-67 antigen was performed using the MIB-1 antibody. The proliferation index was recorded as the percent of all positively stained tumor cell nuclei evaluated. DTI metrics, collagen contents and Ki67 were compared between different subtypes.

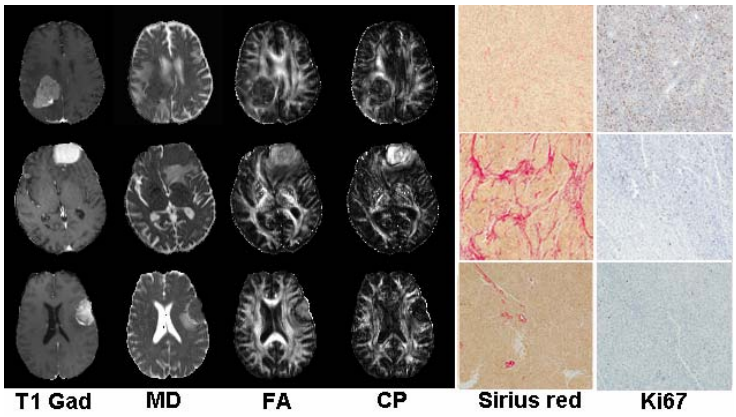

Fig 1. Representative MR images for atypical (upper row), fibroblastic (middle row) and meningothelial (lower row) meningiomas. Fibroblastic meningiomas show high FA, CP and high collagen contents, whereas atypical meningiomas demonstrate high Ki-67.

RESULTS

Representative DTI images and histologic findings including collagen contents and Ki67 are shown in Fig. 1. Boxplots of the DTI imaging parameters from atypical, fibroblastic, transitional and other subtype meningiomas are shown in Fig. 2. Fibroblastic meningiomas demonstrated significantly higher collagen contents compared to other subtypes. Atypical meningiomas showed higher Ki67 compared with typical meningiomas. The median FA and CP values were significantly higher in fibroblastic meningiomas compared to other subtypes and atypical meningiomas. There was a significant positive correlation between FA and collagen content ($r=0.43$, $p<0.05$), and between CP and collagen content ($r=0.35$, $p<0.05$). There was a significant negative correlation between MD and Ki67 ($r=0.36$, $p<0.05$)

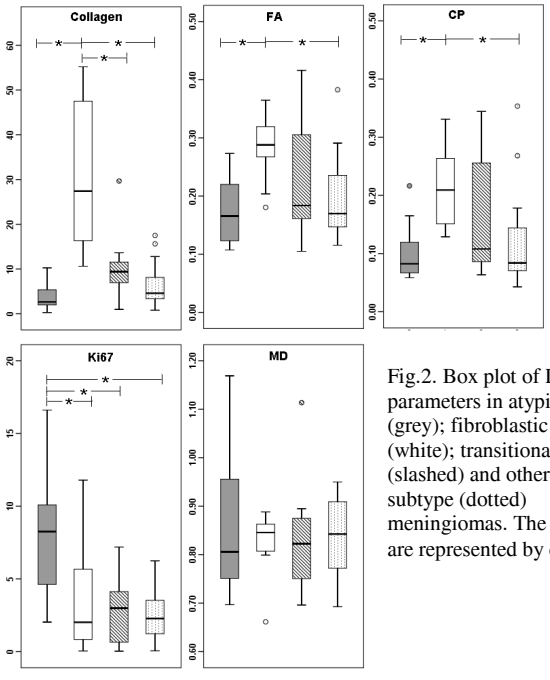

Fig.2. Box plot of DTI parameters in atypical (grey); fibroblastic (white); transitional (slashed) and other subtype (dotted) meningiomas. The outliers are represented by circles.

DISCUSSION

Previous studies[1-4] reported increased FA and CP in fibroblastic meningiomas. Our study confirmed that the high degree of anisotropy within fibroblastic meningiomas is due to their high content of intercellular collagen and reticulin, which is believed to be responsible for the hard consistency of these tumors. Prior studies also demonstrated that MD was able to differentiate atypical from typical meningiomas due to the high cellularity of atypical meningiomas[1]. Our study showed elevated Ki-67 in atypical meningiomas, which correlated with MD. These results suggest that DTI metrics can be helpful in predicting the tumor consistency, histologic grade and tumor recurrence in meningiomas, which can better assist in surgical planning.

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References

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