Apparent diffusion coefficient in meningioma

Increasing evidence suggests that genomic and molecular markers need to be integrated into the grading of meningioma. Telomerase reverse transcriptase promoter (TERTp) mutation is receiving attention due to its clinical relevance in the treatment of meningiomas. The predictive ability of conventional and diffusion MRI parameters for determining the TERTp mutation status in World health organization grade 2 meningiomas has yet been identified.

In this study, 63 patients with surgically confirmed grade II meningiomas (56 TERTp wildtypes, 7 TERTp mutants) were included. Conventional imaging features were qualitatively assessed. The maximum diameter, the volume of the tumors, and histogram parameters from the apparent diffusion coefficient (ADC) were assessed. Independent clinical and imaging risk factors for TERTp mutation were investigated using multivariable logistic regression. The discriminative value of the prediction models with and without imaging features was evaluated.

In the univariable regression, older age (odds ratio [OR] = 1.13, P = 0.005), larger maximum diameter (OR = 1.09, P = 0.023), larger volume (OR = 1.04, P = 0.014), lower mean ADC (OR = 0.02, P = 0.025), and lower ADC 10th percentile (OR = 0.01, P = 0.014) were predictors of TERTp mutation. In multivariable regression, age (OR = 1.13, P = 0.009) and ADC 10th percentile (OR = 0.01, P = 0.038) were independent predictors of variables for predicting the TERTp mutation status. The performance of the prediction model increased upon inclusion of imaging parameters (area under the curves of 0.86 and 0.91, respectively, without and with imaging parameters).

Older age and lower Apparent diffusion coefficient 10th percentile may be useful parameters to predict TERT Promoter Mutation in World health organization grade 2 meningiomas.

Generally, it is not possible to confidently distinguish benign (WHO grade I) and atypical (WHO grade II) from anaplastic (WHO grade III) meningiomas on general morphology.

Diffusion weighted imaging (DWI) along with the calculation of apparent diffusion coefficient (ADC), is a, non-invasive, and reliable technique of choice for accurate assessment and for the treatment planning of different types of brain tumors. It is more advantageous in the distinction and differentiation of benign from malignant meningiomas on the basis of ADC values (reflecting higher cellularity).

For Surov et al., Grade II/III tumors had lower ADC mean values than grade I meningiomas. ADCmean correlated negatively with tumor proliferation index and ADCmin with tumor cell count. These associations were different in several meningiomas. ADCmean can be used for distinguishing between benign and atypical/malignant tumors.

The estimated threshold ADC value of 0.85 can differentiate grade I meningioma from grade II and III tumors. The same ADC value is helpful for detecting tumors with high proliferation potential.

There were several reports describing features of meningiomas on DWI; however, the provided data were inconsistent.

Whereas some authors found an association between ADC and histological parameters of meningiomas, others did not.
In addition, in the analysis of Ginat et al., no association between ADC and Ki-67 level was found \(^{16}\), whereas other authors reported a statistically significant correlation between these parameters \(^{17}\).

Because of the fact that meningioma is the most frequent intracranial tumor and is often an incidental finding on magnetic resonance imaging (MRI), it is important to correctly estimate tumor grade and proliferation potential on imaging \(^{18}\).

ADC values in tumor parenchyma and peritumoral edema can provide helpful information that is otherwise not available from conventional MRI to differentiate hemangiopericytoma (HPC) from angiomatous and anaplastic meningioma \(^{19}\).

Case series

2018

Ko et al., retrospectively investigated the preoperative CT and MR imaging features for the prediction of progression/recurrence (P/R) in skull base meningiomas, with emphasis on quantitative ADC values. Only patients had postoperative MRI follow-ups for more than 1 year (at least every 6 months) were included. From October 2006 to December 2015, total 73 patients diagnosed with benign (WHO grade I) skull base meningiomas were included (median follow-up time 41 months), and 17 (23.3%) patients had P/R (median time to P/R 28 months). Skull base meningiomas with sphenoidal location, adjacent bone invasion, high DWI, and lower ADC value/ratio were significantly associated with P/R (P < 0.05). The cut-off points of ADC value and ADC ratio for prediction of P/R are 0.83 × 10^-3 mm2/s and 1.09 respectively, with excellent area under curve (AUC) values (0.86 and 0.91) (P < 0.05). In multivariate logistic regression, low ADC values (< 0.83 × 10^-3 mm2/s) and adjacent bone invasion are high-risk factors of P/R (P < 0.05), with odds ratios of 31.53 and 17.59 respectively. The preoperative CT and MRI features for prediction of P/R offered clinically vital information for the planning of treatment in skull base meningiomas \(^{20}\).

Pretreatment ADC volumes of 37 meningioma patients (28 low-grade, 9 high-grade) were used for histogram profiling. WHO grade, Ki-67 expression, and progesterone receptor status were evaluated. Comparative and correlative statistics investigating the association between histogram profiling and neuropathology were performed.

The entire ADC profile (p10, p25, p75, p90, mean, median) was significantly lower in high-grade versus low-grade meningiomas. The lower percentiles, mean, and modus showed significant correlations with Ki-67 expression. Skewness and entropy of the ADC volumes were significantly associated with progesterone receptor status and Ki-67 expression. ROC analysis revealed entropy to be the most accurate parameter distinguishing low-grade from high-grade meningiomas.

ADC histogram profiling provides a distinct set of parameters, which help differentiate low-grade versus high-grade meningiomas. Also, histogram metrics correlate significantly with histological surrogates of the respective proliferative potential. More specifically, entropy revealed to be the most promising imaging biomarker for presurgical grading. Both, entropy and skewness were significantly associated with progesterone receptor status and Ki-67 expression and therefore should be
investigated further as predictors for prognostically relevant tumor biological features. Since absolute ADC values vary between MRI scanners of different vendors and field strengths, their use is more limited in the presurgical setting \(^{21}\).

### 2014

MRI examinations and histopathology of 68 surgically treated meningiomas were retrospectively reviewed. Mean ADC values were derived from diffusion imaging. Correlation coefficients were calculated for mean ADC and Ki-67 proliferation index values using linear regression. An independent unpaired Student t test was used to compare the ADC and Ki-67 proliferation index values from low-grade and more aggressive meningiomas.

A statistically significant inverse correlation was found between ADC and Ki-67 proliferation index for low-grade and aggressive meningiomas \((r(2) = -0.33, p = 0.0039)\). ADC values \((± SD)\) of low-grade meningiomas \((0.84 ± 0.14 × 10(-3) \text{ mm}^2/\text{s})\) and aggressive (atypical or anaplastic) meningiomas \((0.75 ± 0.03 × 10(-3) \text{ mm}^2/\text{s})\) were significantly different \((p = 0.0495)\). Using an ADC cutoff value of \(0.70 × 10(-3) \text{ mm}^2/\text{s}\), the sensitivity for diagnosing aggressive meningiomas was 29%, specificity was 94%, positive predictive value was 67%, and negative predictive value was 75%.

ADC values correlate inversely with Ki-67 proliferation index and help differentiate low-grade from aggressive meningiomas \(^{22}\).

### 2012

MR images were reviewed retrospectively in 138 patients with meningiomas treated between September 1997 and July 2003. The ADC values were measured in the lesions and peritumoral edema, and the normalized ADC (NADC) ratios were calculated using the formula \(\text{NADC} = \frac{\text{ADC of the tumor}}{\text{ADC of the normal white matter}}\). The ADC findings were compared with the histopathologic findings after resection using the World Health Organization criteria (2007).

Results: Meningiomas were histologically graded as malignant (9%), atypical (14%) and benign (77%). Of the 138 meningiomas, 32 (23%) were atypical \((n=19)\) or malignant \((n=13)\), whereas 106 (77%) were typical. The mean ADC values were statistically different between typical and atypical/malignant meningiomas \((0.97 ± 0.21 × 10(-3) \text{ mm}^2/\text{s}}\) vs \(0.85 ± 0.17 × 10(-3) \text{ mm}^2/\text{s})\). The mean NADC ratios were also significantly lower in the atypical/malignant group \((1.09 ± 0.23)\) than in the benign group \((1.24 ± 0.25; P=0.002<0.05)\). The mean ADC values and NADC ratios did not differ significantly among fibrous, meningothelial, transitional and atypical tumors \((P>0.05)\). The mean ADC values and NADC ratios were higher in the angiomatous and secretory subgroups than in the fibrous, meningothelial, transitional, atypical and malignant subgroups \((P<0.05)\). The ADC values and NADC ratios were the lowest in the malignant subgroup, and the difference between atypical and malignant meningiomas was statistically significant \((P<0.05)\).

Conclusions: Meningioma subgroups displayed different ADC values from each other. Thus, ADC values may provide a useful supplement to the information obtained from conventional contrast-enhanced MR imaging, enhancing the ability of medical professionals to differentiate among the subgroups of meningiomas \(^{23}\).

\(^{1}\) Shin I, Park YW, Ahn SS, Kang SG, Chang JH, Kim SH, Lee SK. Clinical and Diffusion Parameters may


