Role of ADC values and ratios of MRI scan in differentiating typical from atypical/anaplastic meningiomas

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Abstract
Atypical/anaplastic meningiomas are prone to aggressive behaviour which affects treatment planning and prognostication. Our aim was to assess the role of Apparent Diffusion Coefficient (ADC) values of MRI brain in differentiating typical from atypical/anaplastic meningioma.

We reviewed 84 typical and 37 atypical/anaplastic meningiomas and compared mean ADC values and ADC ratios of their preoperative MRI brain. At 3 Tesla, mean ADC value for typical meningioma was 1.03±0.10x10−3 and 0.63±0.05x10−3 for atypical/anaplastic meningioma. At 1.5 Tesla, mean ADC value for typical meningioma was 1.05±0.11x10−3 and atypical/anaplastic meningioma was 0.70±0.04x10−3. The mean ADC ratios were 1.08±0.17 and 0.85±0.15 for typical and atypical/anaplastic meningomas respectively. Mean ADC ratios and the mean ADC values of typical and atypical/anaplastic meningiomas were significantly different (p<0.001).

ADC values and ADC ratios have important role in differentiating typical from atypical/anaplastic meningioma and it must be part of the routine preoperative MRI reporting.

Keywords: MRI brain, Apparent Diffusion Coefficient, Typical meningioma, Atypical, Anaplastic.

Introduction
Meningioma is the most common primary non-glial intracranial neoplasm. It constitutes about 15% of all primary intracranial tumours.1 Histologically, majority of these tumours are benign, however, 20% of these tumours are atypical or anaplastic (malignant).2

Preoperative disease characterization would be of utmost importance in treatment planning.

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Typical/benign meningioma are confidently diagnosed on magnetic resonance imaging (MRI), but their distinction from atypical/anaplastic by using conventional MRI is still a diagnostic challenge. Heterogeneous appearance and enhancement, oedema around the lesion, and irregular cerebral surface are not consistent and specific neuroimaging features for diagnosing atypical meningioma.3 Atypical/anaplastic have relatively high incidence of brain invasion at the time of surgery which relates to their higher recurrence rate.4

Since the advent of Diffusion Weighted Imaging (DWI), researchers have been exploring to find a role of DWI and Apparent Diffusion Coefficient (ADC) in differentiating typical from atypical tumours including meningiomas. ADC is a calculation of the extent of diffusion of water molecules in the tissue being examined. ADC values are automatically obtained by a software and the values reveal the extent of water molecules diffusion through different tissues.

Few studies have evaluated the role of ADC values and shown statistically significant results in differentiating typical from atypical/anaplastic meningioma, while other studies have contradicted these findings.4-6 A study has also been published from a local center by Bano et al which has found DWI and ADC useful tools in differentiating typical from atypical meningiomas at 1.5T MRI.7 But there is no local data from 3T scanner.

The objective of our study was to evaluate the role of ADC value and ADC ratio of MRI brain in differentiating typical and atypical/anaplastic meningioma.

Materials and Methods
This descriptive retrospective cross-sectional study was approved by departmental ethical review committee of Radiology Department of Aga Khan University Hospital (AKUH). Radiology database was searched through radiology information system. Patients who had a preoperative MRI imaging including Diffusion and ADC imaging on 1.5 T and 3T between the period of January 2014 and December 2016 were included. All patients...
underwent resection and histological diagnosis of meningioma was made along with grading based on 2016 World Health Organization (WHO) classification. The exclusion criteria included patients with abundant calcification, tumour necrosis, post-surgical status and neurofibromatosis associated meningioma. Altogether 121 patients met inclusion and exclusion criteria, 84 were diagnosed as typical and 37 as atypical/anaplastic meningioma.

**Imaging:** 62 patients underwent MR imaging study on a MAGNETOM® Avanto Siemens 1.5 Tesla MR Scanner and 59 patients on Toshiba Vantage TITAN® 3T MR Scanner using standard head coil with 230 X 184 (AP X RL) FOV. Both MRI machines were functional in the department and patients were randomly distributed for imaging on these 2 machines. Conventional MR images consisted of axial and coronal fast spin-echo T2-weighted images (TR/TE 3000/80 ms), axial and sagittal FSE T1-weighted images (8.4/3.8), fluid attenuated inversion recovery sequence (FLAIR) (TR/TE 11000/125), contrast enhanced images T1-weighted images (TR/TE 4.8/3.8) after intravenous contrast injection (gadopentetatedimeglumine - 0.1 mmol/kg) with section thickness of 6 mm and interslice gap of 0.6 mm. DW MR imaging was acquired in the axial plane by using b-values of 0-1000 s/mm2 with section thickness of 5 mm.

Investigator (radiologist) who was blinded to the case and was unaware of the histological diagnosis evaluated the MR images. Conventional MR images were analyzed by T2 and T1 signal intensity. DW and was unaware of the histological diagnosis evaluated the MR images. Conventional MR images were analyzed by T2 and T1 signal intensity. DW

Statistical analyses were made by SPSS 21.0 version for Windows (SPSS, Chicago, IL). Levene's sample test was used for calculating the overall statistical differences among the typical and atypical/anaplastic groups. Student's T-test was conducted for calculating the differences in the mean ADC values and the mean ADC ratios between each pair. P-value <0.05 was considered statistically significant.

**Result**

Patients' mean age was 55.2±13 years with 43 males and 78 females. Majority (55.3%) of the cases presented with headache, followed by seizures, vomiting, weakness and visual loss. Of the 59 lesions imaged on 3T MRI, 12 (20.33%) were atypical/anaplastic and 47 (79.66%) were typical. Of the 62 lesions imaged on 1.5T MRI, 25 (40.33%) were atypical/anaplastic while 37 (59.67%) were typical. The most common tumour location was convexity; 69 (57.02%) cases, followed by parasagittal in 32 (26.44%), sphenoid wing in 14 (11.57%), tentorial in 3 (2.47%), and cerebellar pontine angle in 3 (2.47%) cases.

Diffusion-weighted imaging signal characteristics, ADC values with ranges and ADC ratios with ranges in typical and atypical meningioma at 3T and 1.5T MRI are shown in Table-1. In summary, on diffusion-weighted images, the findings of atypical/anaplastic meningioma and typical meningioma were not significantly different both at 1.5 and 3T MRI.

**ADC findings:** At 3T MRI, the mean ADC value of atypical/anaplastic meningioma was 0.63±0.05 (range 0.57-0.71)x10-3 and the mean ADC value of typical

<table>
<thead>
<tr>
<th>Table-1: DWI imaging characteristics, ADC values, ADC ranges and ADC ratios of typical and atypical meningiomas at 3T and 1.5T MRI.</th>
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<tbody>
<tr>
<td><strong>DWI signals</strong></td>
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<tr>
<td>Hyperintense</td>
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<td>Isointense</td>
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<td>Hypointense</td>
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<td>ADC Values</td>
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<td>A D C T M /A D C W M ratio*</td>
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malignant meningioma was 1.03±0.10 (range 0.77-1.19)x10-3. At 1.5T, the mean ADC value of atypical/anaplastic meningioma was 0.70±0.04 (range 0.64-0.78)x10-3 and the mean ADC value of typical meningioma was 1.05±0.11 (range 0.79-1.21)x10-3. There was a statistically significant difference between the ADC values of typical and atypical/anaplastic meningioma (p<0.001) at both 1.5T and 3T MRI. The mean ADC value of normal white matter was 0.72±0.70 (range 0.60-1.05)x10-3. The calculated mean ADCTM/ADCWM ratios were 1.28±0.17 (range 1.10-1.42) for benign tumours, 0.90±0.15 (range 0.73-1.01) for atypical/anaplastic ones. We found a statistically significant difference between the ADC ratios of typical and atypical/anaplastic meningioma (p<0.001).

## Discussion

Patients with atypical/anaplastic meningioma have increased survival benefits if surgery is followed by fractionated external beam radiation therapy (EBRT) or stereotactic radiosurgery (SRS).

Therefore preoperative characterization of meningioma is of prime importance in deciding the treatment. ADC is a novel, non-invasive, and reliable technique of choice for the preoperative assessment and for the treatment planning of different types of brain tumours. In a previous study, Sanverdi et al. shows correlations between ADC values and tumour grade. In this part of world, only few studies have highlighted the role of ADC value for grading meningioma. Although some studies show that apparent diffusion coefficient (ADC) of atypical/malignant meningioma is significantly lower than benign meningioma, while other studies have concluded that the difference is not statistically significant.

A part from small sample size, the use of a single ROI for each tumour rather than several ROIs was also a limitation of our study.

## Conclusion

Preoperative distinction between typical and atypical/anaplastic meningioma is always demanded by the neurosurgeon for surgical planning and further treatment. ADC values and ratios can be used to distinguish among meningioma grades and it should be essential part of preoperative MRI reporting in meningioma.

## Disclaimer:

None to declare.

## Conflict of Interest:

All authors declare that there is no conflict of interest.

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## References


