CASE SERIES

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 was1.03±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. 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

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underwent resection and histological diagnosis of meningioma was made along with grading based on 2016 World Health Organization (WHO) classification.[8] 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 TITANTM 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 FFET1-weighted images (8.4/3.8), fluid attenuated inversion recovery sequence (FLAIR) (TR/TE 11000/125), contrast enhanced images T1-weighted images (TR/TE8.4/3.8) after intravenous contrast injection (gadopentetatedimeglumine - 0.1 mmol/kg) with section thickness of 6 mm and interslice gap of0.6 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 images were visually inspected and classified as hyperintense, isointense and hypointense as compared with normal white matter. The intratumoural (TM) ADC values were measured with ROI varying from 50-150 mm^2. ROI was placed manually in solid portion of the tumour, avoiding any cystic or calcified area. Control ADC values were also obtained from normal appearing white matter (WM) on the contralateral normal brain tissue unaffected by tumour. The ADCTM/ADCWM ratios were calculated for each patient.

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%), tentorialin3 (2.47%), and cerebellopontine 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-1: DWI imaging characteristics, ADC values, ADC ranges and ADC ratios of typical and atypical meningiomas at 3T and 1.5T MRI.

DWI signals	3T MRI		1.5T MRI	
	Typical	Atypical	Typical	Atypical
Hyperintense	28	9	24	13
Isointense	13	5	11	6
Hypointense	3	1	5	3
ADC Values	1.03±0.10	1.05±0.11	0.63±0.05	0.70 ± 0.04
(Ranges)	(0.77-1.19)	(0.57-0.71)	(0.79-1.21)	(0.64-0.78)
ADCTM/ADCWM ratio*	1.28 ± 0.17	0.90 ± 0.15	1.28 ± 0.17	0.90 ± 0.15
(Ranges)	(1.10-1.42)	(0.73-1.01)	(1.10-1.42)	(0.73-1.01)
Total	44	15	40	22

ADC: Apparent Diffusion Coefficient. ADCTM: Intratumoural Apparent Diffusion Coefficient. ADC/WM: Apparent Diffusion Coefficient of White Matter.

Table-2: Comparison between ADC values of typical and atypical meningioma in this study and previous similar studies.

Authors	Typical Meningioma	Atypical Meningioma
Hakyemez et al. [2]	1.17±0.21 (1.5T)	0.75±0.21
Filippi et al. [4]	1.03±0.29 (1.5T)	0.52 ±0.12
Nagar et al. [6]	0.88±0.08 (1.5T)	0.66±0.13
Bano et al [9]	1.04±0.12 (b1000) (1.5T)	0.64±0.05 (b1000)
	0.80 ±0.07 (b2000) (1.5T)	0.42± 0.03 (b2000)
Gupta et al. [10]	0.82 ± 0.12 (3T)	0.68±0.10 (3T)
	0.83±0.11 (1.5T)	0.70 ± 0.09 (1.5T)
This study	1.03±0.10 (3T)	0.63±0.05 (3T)
	1.05±0.11 (1.5T)	0.70 ± 0.04 (1.5T)

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).[9] Therefore pre-operative 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[5] 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.[4-6]

Literature search reveals similar study performed on 1.5 and 3T simultaneously by Sasaki et al. observed that there is a significant variability in ADC values between 1.5 and 3T scanners and relative ADC values may be more suitable than absolute ADC values for comparison of studies involving different strength scanners.[10] In this study, patients were classified separately depending upon scanner used to prevent fluctuation in mean ADC values. In addition, ADCTM/ADCWM ratios were used to eliminate the inter-scanner variability. Similar observations were also found in previous international studies performed by Santelli and Sanverdi et al.[6]

In this study, we found that the ADC values of atypical/anaplastic meningioma were significantly lower than those of normal white matter and typical meningioma both at 1.5 and 3T MRI. Comparable results have been observed by other authors, summarized in Table-4.[2,4,6,7,11] These studies concluded that ADC values play significant role in grading of meningiomas. In addition to that they also found that higher the b values the greater the sensitivity of ADC.

In this study, we have evaluated the role of ADC at 3T MRI which is the first study of its type in the country as 3T scanner is scarcely available in Pakistan.

Apart 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.

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Conflict of Interest: All authors declare that there is no conflict of interest.

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