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Original Article

Diffusion weighted imaging may help differentiate intracranial hemangiopericytoma from meningioma

Jai Jai Shiva Shankar [a,b,*], Luke Hodgson [b], Namita Sinha [c]

[a] Department of Radiology, University of Manitoba, Winnipeg, Canada
[b] Department of Diagnostic Radiology, Dalhousie University, Halifax, Canada
[c] Department of Pathology, University of Manitoba, Winnipeg, Canada

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ABSTRACT

Background and purpose. – Hemangiopericytoma and meningioma appear similar on routine diagnostic imaging and hence are difficult to distinguish. The purpose of our study was to examine the diffusion weighted imaging (DWI) characteristics of these two types of tumours.
Methods. – In a retrospective study, each patient with hemangiopericytoma was matched with two meningioma patients based on tumour location and size. Minimum and mean apparent diffusion coefficients (ADC) were measured in the tumour and the contralateral normal-appearing white matter (NAWM). A normalized ADC was calculated. The two tumour types were subjectively assessed for heterogeneity on ADC maps.
Results. – Of the 14 patients with histopathological proven hemangiopericytoma, only 7 had available DWI for analysis. These 7 patients were matched based on tumour location and size with 14 patients out of the 209 meningioma patients screened. Hemangiopericytomas were more heterogeneous on ADC maps ($P < 0.001$) and had a higher mean ADC compared to that of meningiomas ($P < 0.001$).
Conclusion. – Hemangiopericytomas showed heterogeneity on DWI and significantly higher ADC compared to that of meningiomas in our small study. These observations need to be confirmed in future studies with larger sample sizes.

Introduction

Hemangiopericytoma was first described in 1942 as an uncommon neoplasm that originates from the Zimmerman pericytes in the walls of capillaries [1,2]. Hemangiopericytomas are found in the musculoskeletal system and the skin, but rarely in the central nervous system. The meningeal hemangiopericytomas make up <2.5% of all meningeal tumours and <1% of all intracranial tumours [2]. Hemangiopericytomas appear identical to meningiomas on routine diagnostic imaging, but have a much more aggressive natural history [1,3] and must be treated aggressively with surgical resection, chemotherapy or radiotherapy [4,5].

Meningiomas account for 20% of all intracranial neoplasms, and are more common in females. They are typically found in patients older in age (> 30) because the incidence for this type of tumour increases with age [6]. These tumours are usually classified as being benign, but atypical or malignant variants are not uncommon. Most meningiomas do not need to be treated but if they must, they can be treated by surgical resection or by radiation therapy [7,8].

These two tumour types appear very similar on routine diagnostic imaging, but they have a very different natural history. Although hemangiopericytomas are solitary in nature, show vascular channels; propensity for bone erosion; lack of hyperostosis and calcification and presence of brain edema on imaging, the final diagnosis is only made on histopathological examination. Diffusion weighted imaging (DWI) and apparent diffusion coefficient (ADC) measure the magnitude of diffusion of water molecules within a tissue. DWI and ADC have been used in differentiation of tumour types [9–12]. The purpose of our study was to assess the DWI characteristics of the two tumour types.

Methods

The study was approved by our institutional research ethics board. In a retrospective study, our tumour database was searched for diagnosis of hemangiopericytoma with DWI available at the time of diagnostic magnetic resonance imaging (MRI). These patients were then matched to patients with known meningioma based on location and size of the tumour in a ratio of 1

* Corresponding author at: Department of Radiology, University of Manitoba, Winnipeg, MB R3L0E9, Canada.
E-mail address: shivajai1@gmail.com (J.J.S. Shankar).

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Table 1
Demographic and imaging characteristics of the patients with hemangiopericytoma.

No	Age	Sex	Size (mm)	Appearance	Mean ADC (mm^2/s)	Min ADC (mm^2/s)	nADC	Location
1	53	F	38.9	Homo	1090	760.8	1.38	Posterior fossa
2	51	F	47.3	Hetero	851.37	647	1.03	Posterior fossa
3	41	M	38.7	Hetero	1331	927.9	1.70	Foramen Magnum
4	64	M	23.4	Hetero	1060.37	972.4	1.54	Posterior fossa
5	45	F	62.1	Hetero	1217.67	1049	1.69	Posterior fossa
6	1	M	79.5	Hetero	1201	597.7	1.19	Convexity
7	79	F	68.1	Hetero	1391.22	1235	1.82	Parasagittal

M: male; F: female; ADC: apparent diffusion coefficient; Min ADC: minimum ADC; nADC: normalized ADC; Homo: homogenous; Hetero: heterogeneous.

Table 2
Demographic and imaging characteristics of the patients with meningioma.

No	Age	Sex	Size (mm)	Appearance	Mean ADC (mm^2/s)	Min ADC (mm^2/s)	nADC	Location	Histological Grade
1	65	F	36.4	Homo	679.22	604.3	0.83	Posterior fossa	Grade 1
2	63	F	35.3	Homo	597.33	467.4	0.75	Posterior Fossa	Grade 1
3	53	F	44.9	Homo	849.63	730.3	1.13	Posterior fossa	Grade 1
4	56	F	47.3	Homo	822.2	763.2	0.98	Posterior fossa	Grade 1
5	44	F	35.5	Homo	796.7	788.4	1.07	Posterior fossa	Grade 1
6	79	M	30.3	Hetero	994.25	892.8	1.32	Posterior fossa	Grade 1
7	66	M	26.2	Homo	898.47	873.9	1.02	Posterior fossa	Grade 1
8	78	M	25.1	Hetero	856.77	809.3	0.94	Posterior fossa	Grade 1
9	54	M	65.1	Hetero	1052.1	850.3	2.61	Right sphenoid wing	Grade 2
10	63	F	59.7	Homo	987.9	750.8	2.57	Left convexity	Grade 1
11	68	M	52.6	Hetero	876.94	634.4	1.10	Right convexity	Grade 1
12	63	M	54.5	Homo	851.52	734.5	2.19	Right convexity	Grade 1
13	42	F	50.6	Hetero	965.75	854.2	2.25	Left convexity	Grade 1
14	74	M	58.6	Hetero	866.46	703	0.97	Left parasagittal	Grade 1

M: male; F: female; ADC: apparent diffusion coefficient; Min ADC: minimum ADC; nADC: normalized ADC; Homo: homogenous; Hetero: heterogeneous.

hemangiopericytoma to 2 meningioma. From 2008 to 2014, a total of 209 patients with confirmed meningioma and 14 patients with hemangiopericytoma were screened. Each patient with hemangiopericytoma was matched according to the location and size of their tumour with 2 patients with meningioma. The patients with the following images on their diagnostic MRI were included in the study:

- DWI;
- ADC maps;
- T1 post gadolinium images;
- axial fluid-attenuating inversion recovery (FLAIR) images; and;
- T2 images.

Image acquisition

All patients underwent MRI on a 1.5 T magnet scanner (Singa, GE Healthcare). The brain tumour imaging protocol in our institute included DWI, T1 pre and post gadolinium, T2, and FLAIR images of the brain. The DWI was acquired by using single-shot echo-planar imaging with 8000 ms TR, 73.6 ms TE, 260-mm FOV, 160×192 matrix size, 5-mm section thickness with 1.5 mm intersection gap, and 1000 and 0 mm^2/s b-values obtained in 3 orthogonal directions. FLAIR images were acquired as fast spin echo images by using 8000 ms TR, 120 ms TE, 2000 ms TI, 220-mm FOV, 256×254 matrix size, 5-mm section thickness with 1.5 mm intersection gap. Post-contrast T1W images were as acquired as fast spin echo images by using single-shot echo-planar imaging with 500 ms TR, 22.8 ms TE, 220-mm FOV, 320×192 matrix size, 5-mm section thickness with 1.5 mm intersection gap.

Image analysis

Patient retrieval and image analysis was performed by a single reviewer (LH) on the Picture Archiving and Communication System (PACS) workstations in the department of Diagnostic Imaging under the guidance of a fellowship trained neuroradiologist (JS). Comparisons between the patients with hemangiopericytoma and meningioma were made for age, gender, location of the tumour, appearance of the tumour, size of the tumour, and mean and minimal ADC. Each tumour was subjectively labelled homogeneous or heterogeneous based on their heterogeneity on DWI and ADC maps by a single reviewer (JS).

The dimensions of each tumour were measured on the axial and coronal T1 FSE post gadolinium image using the markup caliper tool. The largest dimension of each tumour was then used to make comparisons between the two tumour types. On the ADC map, the tumour was manually outlined on each image slice using a freeform markup tool, and a mean ADC value was obtained. The minimum ADC was subjectively called the most hyperintense foci on DWI with the most hypointense foci on the ADC map. The minimum ADC value was measured using the ellipse markup tool.

The ADC in the normal-appearing white matter (NAWM) was measured as a mean from the bilateral centrum semiovale. In patients, where one of the centrum semiovale was involved by the tumor or associated vasogenic edema, ADC was calculated from only one side centrum semiovale. An ellipse markup tool was used to obtain this value. A normalized ADC was then calculated as the ratio of ADC in tumour with that in NAWM.

Statistical analysis

Two-sample *t*-tests were performed for comparisons of age of the patients, size of the tumours, mean and minimum ADC, mean ADC in NAWM, and normalized ADC values. Chi^2 test was used to compare the subjective heterogeneity of the two tumors. A *P*-value of less than 0.05 was considered significant. A contingency table analysis of statistical measures including the sensitivity, specificity, and positive and negative predictive values was derived.

Results

Of the 14 patients with histopathologically proven hemangiopericytoma, only 7 patients had DWI available at the time of diagnosis. These 7 patients were then matched by their tumour's

Table 3
Comparison of demographic and imaging characteristics between patients with meningioma vs. those with hemangiopericytoma.

Parameters	*P*-value
Age	0.076
Sex	0.77
Size	0.35
Heterogeneity	<0.001[a]
Mean ADC	<0.001[a]
Min ADC	0.081
nADC	0.80

ADC: Apparent Diffusion Coefficient; Min ADC: Minimum ADC; nADC: Normalized ADC.
[a] Denotes significant difference ($P < 0.05$).

location and size to 14 patients screened out of 209 patients with meningioma. The mean age of the patients with meningioma (mean: 62 years, range: 42–79 years) and hemangiopericytoma (mean: 47.7 years, range: 1–79 years) were not significantly different ($P = 0.07$). The gender distribution in both tumour groups was fairly equal ($P = 0.77$). Most of the hemangiopericytoma and meningioma patients were matched for their location and size (Tables 1 and 2,). Patient 5 with hemangiopericytoma could only be matched for size.

The mean age (62 vs. 47.7), mean size (44.4 vs. 51.1 mm), mean ADC in NAWM (698.9 vs. 797.4 mm^2/s), minimum ADC value (746.9 vs. 884.2 mm^2/s), and normalized ADC (1.4 vs. 1.5) were not significantly different between hemangiopericytoma and meningioma respectively (Table 3). The mean ADC value for hemangiopericytoma ($1163.23 \pm 134.47\ mm^2/s$) was found to be significantly higher than that of meningioma (863.94 ± 63.55) (Table 3 and Fig. 1). On subjective evaluation, hemangiopericytomas appeared heterogeneous in appearance on DWI and ADC maps compared to the more homogenous appearance of meningiomas ($P = 0.06$) (Fig. 2). If we exclude radiation induction or atypical grade II meningiomas, the primary meningiomas with no osseous involvement appeared significantly homogeneous compared to the heterogeneous appearance of hemangiopericytomas (Table 3). The radiation induced meningiomas, those with osseous involvement, and atypical grade II meningiomas (Fig. 3) appeared heterogeneous (Table 2). All of the hemangiopericytoma tumours were heterogeneous, except for Patient 1, which appears homogenous (Table 1). This

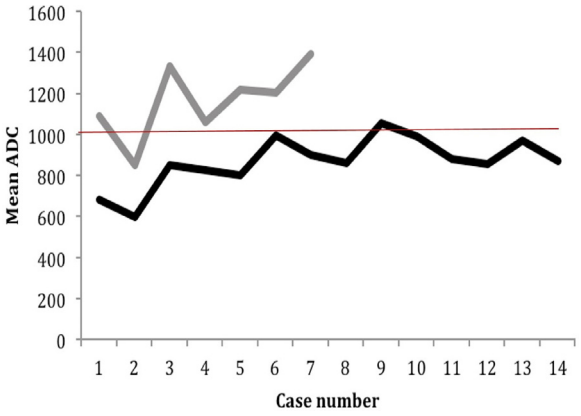

Fig. 1. A comparison of the mean ADC values between hemangiopericytoma (grey) and meningioma (black). The odds ratio for diagnosis of hemangiopericytoma above a mean ADC > 1000 mm^2/s was found to be 78.

Table 4
Contingency table analysis for mean ADC and heterogeneous appearance of hemangiopericytoma.

	Sensitivity	Specificity	PPV	NPV
Mean ADC > 1000 mm^2/s	87.7%	92.8%	87.7%	92.8%
Heterogeneous Appearance	87.7%	57.14%	50%	88.9%

ADC: apparent diffusion coefficient; PPV: positive predictive value; NPV: negative predictive value.

patient had a mean ADC value of 1090 mm^2/s, which numerically corresponded to hemangiopericytomas, but on subjective evaluation, it appeared much more homogenous similar to meningiomas.

Table 4 summarizes the contingency table analysis for heterogeneous appearance of hemangiopericytoma and mean ADC at a cut-off value of 1000 mm^2/s. The odds ratio for a tumour with mean ADC value above 1000 mm^2/s of being a hemangiopericytoma was 78.

Discussion

DWI has an advantage over other methods of advanced imaging as it is quick, is more reproducible, and does not require con-

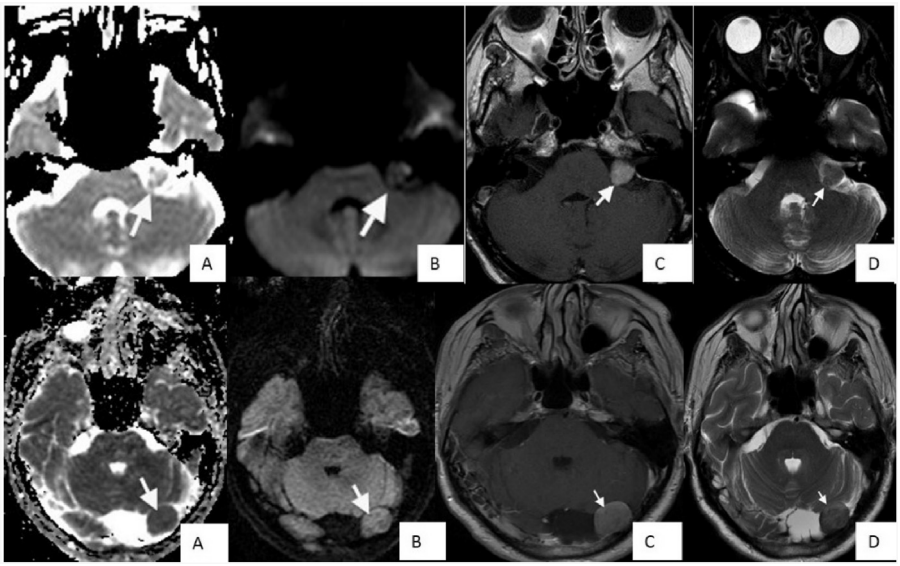

Fig. 2. The top row is Patient 4 with hemangiopericytoma showing heterogeneous appearance and the bottom row is Patient 7 with meningioma showing homogenous appearance on A. Apparent diffusion coefficient (ADC) map. B. Diffusion weighted imaging (DWI). C. Post gadolinium T1. D. T2 images, with a mean ADC value at 1060.37 mm^2/s in hemangiopericytoma and 856.77 mm^2/s in meningioma.

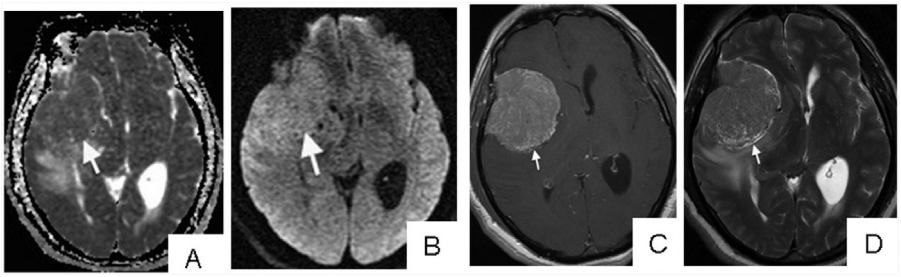

Fig. 3. Patient 9 with meningioma. A. Apparent diffusion coefficient (ADC) map. B. Diffusion weighted imaging (DWI). C. Post gadolinium T1. D. T2 images, which is an atypical grade II meningioma that had a higher mean ADC value of 1052.1 mm^2/s.

trast injection [13]. Based on findings from the present study, hemangiopericytomas showed higher ADC values compared to meningiomas. Mean ADC value of above 1000 mm^2/s showed very high sensitivity, specificity, positive and negative predictive values for diagnosis of hemangiopericytoma. Overall, hemangiopericytomas tend to be more heterogeneous compared to meningiomas on ADC maps.

On the subjective assessment of heterogeneity, the primary meningiomas with no osseous involvement, radiation induction or atypical grade II meningiomas appeared significantly homogeneous compared to the heterogeneous appearance of hemangiopericytomas ($P < 0.001$). The radiation induced meningiomas, those with osseous involvement, and atypical grade II meningiomas also appeared heterogeneous. All hemangiopericytomas were heterogeneous, except for Patient 1, which appears homogenous.

Patient 2 with hemangiopericytoma had a lower ADC value (Table 1), but appeared heterogeneous similar to the rest of hemangiopericytomas in our group. On histopathology, the cells were very densely packed in storiform pattern and in pattern-less pattern. The nuclei are round to oval with open chromatin, and there are 4 mitoses in 10HPF. No areas of necrosis were found. The aberrant appearance on DWI may be explained by increased cellularity in this particular case.

Based on our study, we propose that patients with extra-axial tumour suspicious for meningioma should be evaluated for its heterogeneity and mean ADC. If the tumour does not have osseous involvement on routine imaging, appears heterogeneous and has a mean ADC of more than 1000 mm^2/s, it is more likely to be a hemangiopericytoma than meningioma. The caveat is the atypical higher grade meningiomas that may not follow this rule. However, the higher grade meningioma, owing to aggressive behaviour including brain invasion, will nevertheless need aggressive treatment.

The difference in diffusion characteristic in these tumours may possibly be due to the cell types and differences in the ratio of extracellular to intracellular space. In hemangiopericytoma, the cells are arranged around thin-walled staghorn vascular spaces and the cell membrane is separated from each other by a wide extracellular space with intercellular matrix, especially reticulin deposition around individual tumour cells [14,15]. Desmosomal attachment, which forms a distinct and constant feature of meningioma is not present in hemangiopericytoma [15,16]. On the other hand, meningioma cells are tightly connected by intercellular cell junctions with packed intercellular areas by numerous cytoplasmic processes with increased intracellular complex protein molecules [16]. Therefore, meningiomas may potentially have less extracellular space and more intracellular space, restricting the net water diffusion compared to that of hemangiopericytomas. This histological difference may explain the difference on the ADC map. The increased extracellular reticulin may also result in the increase in ADC in hemangiopericytomas. However this need to be further studied in future research.

A recent study by Mama et al highlighted the value of diffusion imaging and MR spectroscopy in characterization of hemangiopericytoma [17]. However, they did not have a control group of meningioma patients. Liu et al studied ADC values in differentiating the intracranial hemangiopericytomas from angiomatous and anaplastic meningiomas [18]. They did not find any significant difference between angiomatous meningioma and hemangiopericytoma. Whereas they found lower ADC and normalized ADC ratios for anaplastic meningioma than for either angiomatous meningioma or hemangiopericytoma ($P < 0.05$). Interestingly they did not find any significant difference between ADC values in anaplastic versus angiomatous meningiomas. Liu et al described lower minimum ADC in meningioma versus hemangiopericytoma [19]. They did not report the mean ADC and did not match their meningioma with hemangiopericytoma based on location and size. Our study has compared the size and site matched hemangiopericytomas with meningiomas and found significantly lower mean ADC in the former group. Our study is the only one with the subjective comparison of the appearance of the two tumour groups on DWI.

Limitations

Our study was a retrospective study comprised of a small number of patients. However, given the rarity of hemangiopericytomas and their aggressive natural history, our study will serve an important purpose of differentiating them from meningiomas. Due to the retrospective nature of the study, we did not have any molecular explanation for our diffusion characteristics. This is an important scope for future research in this field.

Conclusion

Our small study suggest that hemangiopericytoma showed heterogeneity on DWI and significantly higher ADC compared to that of meningioma. This difference in DWI characteristics may be helpful in differentiating hemangiopericytomas from meningiomas. A prospective study with larger sample size is needed to confirm the findings of our small study.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Disclosure of interest

The authors declare that they have no competing interest.

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