Value of Apparent Diffusion Coefficient (ADC) and Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) in Differentially Diagnosing Angiomatous Meningiomas and Solitary Fibrous Tumors/Hemangiopericytomas

Authors' Contribution:
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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: To determine if ADC and DCE-MRI can be used to differentiate angiomatous meningiomas (AMs) from solitary fibrous tumors/hemangiopericytomas (SFT/HPCs).

Material/Methods: We retrospectively reviewed records of 103 patients from 1 January 1 2014 to 1 November 2018. We enrolled 41 patients who had undergone a 3T MRI, with histologically confirmed AMs in 20 (48.80%) patients, and SFT/HPCs in 21 (51.20%) patients. The ADC and DCE-MRI features were derived and then compared by 2 independent-samples t tests and Wilcoxon rank sum test to obtain the ROC.

Results: AMs had significantly lower ADC values than did SFT/HPCs, but AMs had significantly higher MCER values than did SFT/HPCs. A threshold value of 1.03×10^{-3} mm^2/s for ADC to predict AMs from SFT/HPCs was estimated (AUC=0.902, sensitivity=88.20%, specificity=83.30%). Optimal diagnostic performance (AUC=0.825, sensitivity=84.60%, specificity=81.80%) was obtained when setting MCER=226.7% as the threshold value.

Conclusions: The ADC values of AMs were lower than those of SFT/HPCs; the MCER of AMs were greater than those of SFT/HPCs, and ADC was more useful than MCER, and these parameters could help diagnosis.

MeSH Keywords: Brain Neoplasms • Diffusion Magnetic Resonance Imaging • Magnetic Resonance Imaging

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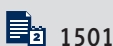
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Background

Histopathologic examination is still the criterion standard for diagnosis of tumors, but surgical biopsies have potential morbidity and mortality risks, as the error rate of intraoperative microscopic diagnosis is reported to be 3–8% [1]. Thus, an accurate diagnosis in neuroimaging before treatment is necessary.

Solitary fibrous tumors/hemangiopericytomas (SFT/HPCs) are highly vascularized tumors, which are known for their malignancy, invasiveness, and high vascularization [2], accounting for 2–3% of all primary meningeal tumors, and they are believed to originate from Zimmerman pericytes [3]. Angiomatous meningiomas (AMs) are benign tumors that are classified as a relatively rare subtype of grade I meningiomas by the WHO. From 2003 to 2008, AMs accounted for 2.59% of all meningiomas [4].

Studies have assessed the abilities of dynamic computed tomography, immunohistochemical analysis, and histograms of ADC to predict AMs from SFT/HPCs [2,5,6]. The purpose of the present study was to analyze the abilities of ADC and DCE-MRI to differentiate AMs from SFT/HPC by the value of apparent diffusion coefficient (ADC), time signal intensity curves (TIC), maximum signal intensity (SImax), the time to maximum (Tmax), maximum contrast enhancement ratio (MCER), and early enhancement ratio (EER).

Diffusion MR imaging is a noninvasive imaging method that provides information about the speed of diffusion of water molecules through tissue. The speed of diffusion is inversely proportional to the integrity of the tissue studied, quantified by the apparent diffusion coefficient (ADC) [7]. DCE-MRI can give information not only about the blood flow of tumors, but also about differentiation of necrotic tissue.

Material and Methods

Patients

This retrospective study was approved by the Institutional Ethics Review Committee of our hospital. Using the surgical pathology database for the period of 1 January 2014 to 1 November 2018 in our hospital, the patients who met the following criteria were enrolled: (1) the primary tumors were histopathologically confirmed by biopsy or surgery; and (2) the tumors were chosen when AMs were misdiagnosed as SFT/HPCs in PACS or SFT/HPCs were misdiagnosed as AMs.

Exclusion criteria were: (1) had received treatment before surgery; (2) not confirmed histologically by biopsy; and (3) inadequate image quality. A total of 41 patients, including 20 AMs and 21 SFT/HPCs, met the inclusion criteria for our study.

All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was obtained.

Image analysis

We used an MRI scanner with a standard head coil. The MRI scan protocols were: axial T1WI (TR/TE=260.0/2.46 ms); axial T2WI(TR/TE=3800/93.0 ms); axial FLAIR(TR/TE=4500/93.0 ms); sagittal T2WI (TR/TE=4200/79 ms); axial DWI (b=0 and 1000 s/mm^2, TR/TE=3500/119 ms, field of view=230 mm, thickness=5 mm, intersection gap=0.3 mm, and layers=20); and contrast-enhanced T1WI (flow rate=2.0 mL/s, dose=0.2 ml/kg).

For enhanced-T1WI, DWI, and T2WI on the maximum layer of the tumor level, we manually placed the region of interest (ROIs) of ADC maps of b = 1000 by the collaborators who did not know the tumor types in a Siemens Syngo post-processing workstation, avoiding cystic, necrotic, and hemorrhage tissues, and the field of view was 20 to 50 mm. The ADC value was measured 3 times, and then the average was obtained.

Mean-Curve software was used to process DCE-MRI data, and the type of TIC was obtained. Type I shows a rapid rise in the early stage, and then decreases to a plateau after reaching a peak (Figure 1). Type II rapidly rises to a plateau. Type III is a continuous rise. SImax means maximum signal intensity; Tmax means the time to maximum; MCER means maximum contrast enhancement ratio; EER means early enhancement ratio. $MCER=(SImax–SI_0)/SI_0×100\%$ (SI_0 is the signal intensity before enhancement) and $EER=(SI_1–SI_0)/SI_0×100\%$ (SI_1 is the signal intensity at the end of the first phase after the enhancement).

Statistical analysis

We used the independent-samples t test and Wilcoxon rank sum test. Sensitivity, specificity, and area under the curve were calculated for the diagnostic procedures. Thresholds were chosen to maximize the Youden index. All statistical analyses were performed using SPSS (SPSS 23.0). A P value <0.05 was considered to be statistically significant.

Results

From January 2015 until November 2018, a total of 73 patients were potentially eligible for inclusion. However,12 patients were excluded due to lack of an MRI scan in the PACS, 9 patients were excluded because they lacked enhanced-T1WI, and 11 patients were excluded because of surgery before MRI. Thus, a total of 41 patients were finally selected for the study. We included 20 patients with AMs and 21 patients with SFT/HPCs. More details about tumor characteristics are provided in Table 1.
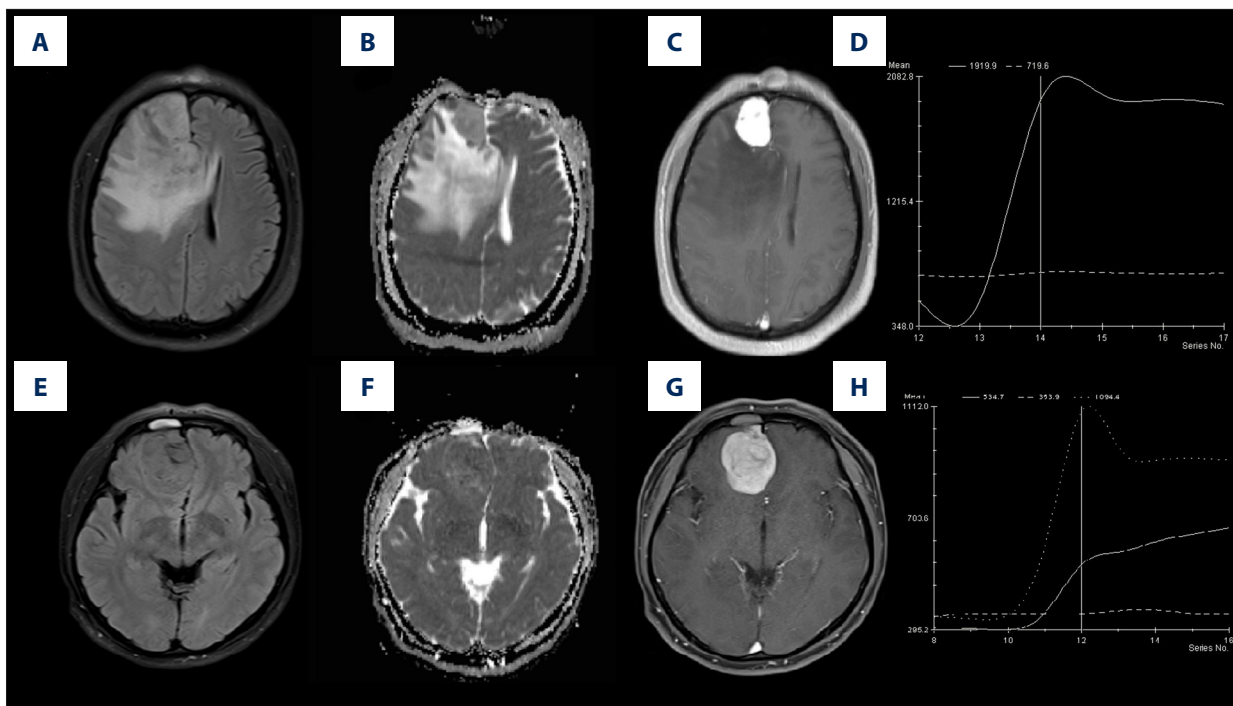
Figure 1. Representative cases of AM (**A–D**) and SFT/HPC (**E–H**). The column shows axial Flair, ADC, Enhanced-T1WI of a 60-year-old male patient with AM (**A–C**), and that of a 30-year-old man with SFT/HPC (**E–G**). Types of TIC were conducted (**D, H**) and belonged to type I and type III, respectively.

Table 1. Characteristics of patients with AMs and SFT/HPCs.

	AMs	SFT/HPCs
Number	20	21
Age	57.65±1.42	51.89±2.98
Sex		
Male	12	6
Female	8	15
Type of TIC		
I	3	11
II	11	5
III	6	5

Non-normally distributed data are described by median, and normally distributed data are described by means.

There was a significant difference between ADC and MCER values (Table 2). SImax, Tmax, and EER were not significantly different. AMs showed significantly lower ADC values than did SFT/HPCs. AMs had significantly higher MCER values than did SFT/HPCs.

AUCs for the most significant parameters were shown in Table 3. The ADC value had the better discriminative power to differentiate AMs from SFT/HPCs, with an optimal cutoff value of 1.03×10^{-3} mm^2/s, yielding a sensitivity of 88.20% and a specificity of 83.30%. The optimal diagnostic performance (AUC=0.825, sensitivity=84.60%, specificity=81.80%) was obtained when setting MCE=226.7% as the threshold value (Figure 2).

Table 2. Parameters of patients with AMs and SFT/HPCs.

	AMs	SFT/HPCs	p
ADC (10^{-3} mm^2/s)	0.91±0.03	1.20±0.05	0.000
SImax	1379.82±149.25	1230.10±89.18	0.400
Tmax (s)	77.39±10.40	78.37±11.17	0.949
MCER (%)	289.10	143.70	0.006
EER (%)	1.60	0.80	0.820

Table 3. ROC analysis of ADC histogram features for discriminating AMs and SFT/HPCs.

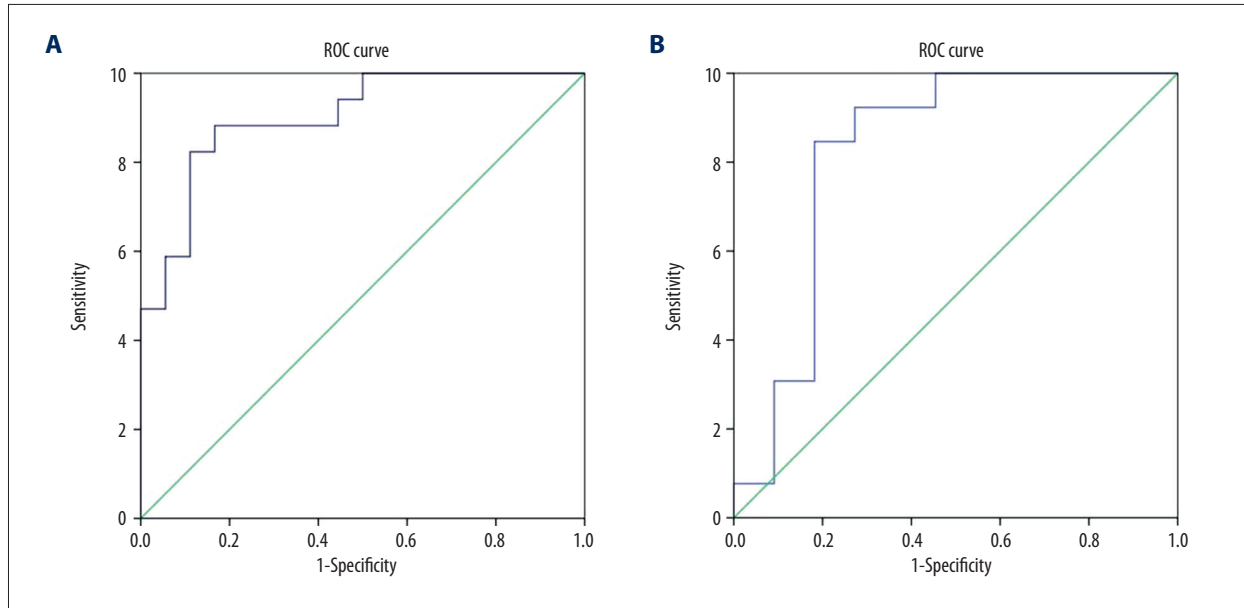|	AUC	Cutoff value	Sensitivity	Specificity	p
ADC (mm²/s)	0.902±0.051	1.03×10^{-3}	88.20%	83.30%	0.000
MCE R(%)	0.825±0.098	226.70	84.60%	81.80%	0.007

Figure 2. The left picture (**A**) shows ROC curve of ADC value. The right picture (**B**) shows the ROC curve of MCER for differentiating AMs and SFT/HPCs.

Discussion

The purpose of this study was to analyze the abilities of ADC and DCE-MRI to differentiate between AMs and SFT/HPCs. Local recurrence after resection of SFT/HPCs was higher, and distant metastasis was up to 23% [8], while AMs after surgical resection could have a benign prognosis [9–11]. It is therefore critical to distinguish SFT/HPCs from AMs to determine therapeutic planning, such as preoperative embolization, gross total resection followed by radiotherapy of patients with SFT/HPCs [12], and surgical resection alone of patients with AMs [5].

A previous study of 523 patients found that the mean age of all patients with SFT/HPCs was 44.17(±3.59) years and the male: female ratio was 1.04: 1, without significant sex differences, but for patients younger than 45 years of age, the ratio was 1.17: 1, and for those over age 45 the ratio was 0.83: 1 [13]. AMs showed a male predilection [14], consistent with our study, while Hasselblatt et al. reported a higher predominance in females, and the sex ratio was 0.73: 1 [15]. These conflicts need to be resolved in a larger cohort study.

ADC values

DWI provides information about the diffusion of water molecules [16]. Tumor cellular density and grade are related with ADC values; generally, the higher the grade of tumors, the lower the ADC values [17].

Liu et al. found that the mean ADC in AMs was higher than in SFT/HPCs, but it did not differ significantly, and there were no statistically significant differences [18]. Kanazawa et al. found the mean ADC value was lower in SFT/HPCs [12]. They speculated that this may be due to the increase of mitotic activity and the decrease of extracellular fluid compartment in SFT/HPCs [19]. Meng et al. found ADC values in AMs were lower than in SFT/HPCs, consistent with our study, and hypothesized that this may be related to the degree of differentiation and plentiful vasculature in tumor parenchyma in SFT/HPCs [20]. Further research with larger samples is needed.

DCE-MRI values

DCE-MRI is able to provide some information about lesion perfusion, microvascular permeability, and extracellular volume [21].

Yang et al. found that 14 of 15 patients with SFT/HPCs around the orbit showed type I TIC [22], but they did not clarify histological subtypes. Garcia-Bennett et al. studied 4 SFT/HPCs in soft tissue and reported that 3 tumors were type I and only 1 was type III [23]; the former 3 tumors were classified as cellular form and the latter was a giant cell variant of SFT. Nagata et al. found that 8 patients (7 cellular and 1 fibrous SFT/HPCs) had a rapid increase in enhancement and 6 (all fibrous SFT/HPCs) had a gradual enhancement pattern [24] . They hypothesized that cellular SFT/HPCs showed rapid enhancement relating to abundant staghorn branching vessels, and fibrous SFT/HPCs may be correlated with numerous fibrous stroma and many medium-sized ramified vessels. SFT/HPCs tended to show heterogeneous enhancement and necrosis due to its aggressiveness and fast growth. AMs usually show homogeneous enhancement, but 1 was reported to have a large volume, and necrosis was rare [20]. In our study, in addition to classifying types of TIC, we determined and compared the values of SImax, Tmax, MCER, and EER of the 2 kinds of tumors, although only MCER was significantly different between groups. AMs had significantly higher MCER values than SFT/HPCs and this method may help in differentiating these 2 tumors.

Our study has some limitations. First, the size of the sample was small, and further studies with larger samples are needed. Second, other important meningiomas, such as anaplastic meningiomas, were missing from our study population. Finally, future research with application of advanced methods such as DTI or ASL should be performed [25–27].

Conclusions

This study showed that ADC and DCE-MRI can improve the diagnostic ability to differentiate AMs and SFT/HPCs, and ADC is more valuable than MCER.

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