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Differentiation of Posterior Fossa Schwannomas from Meningiomas Using ADC Values

Posterior Fossa Schwannomlarının Menenjiyomlardan ADC Değerleri ile Ayrımı

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Abstract

Objective: To assess the diagnostic efficiency of apparent diffusion coefficient (ADC) values in differentiating posterior fossa schwannomas and meningiomas.

Methods: A total of 55 patients who were referred for magnetic resonance imaging (MRI) of posterior fossa extra-axial lesions were retrospectively enrolled in our study. Tumors were classified based on the patients' conventional MRI findings. The mean ADC values of the tumor and reference value from contralateral cerebellar parenchyma were obtained by using region of interest from ADC maps by two radiologists in consensus. ADC ratios were calculated. Differences between schwannomas and meningiomas in mean ADC, and ADC ratio values were statistically analyzed.

Results: 52.7% of patients were male, 47.3% were female with a mean age of 53.4. Based on conventional MRI features, 29 were interpreted as schwannoma, 26 as meningioma. Mean ADC values ($\times 10^{-3}$ mm^2/s) of schwannomas and meningiomas were 1.087±0.224 and 0.729±0.130, respectively. Mean ADC ratios were 1.56±0.34 for schwannomas and 1.08±0.17 for meningiomas. Mean ADC values and ADC ratios of schwannomas were significantly greater than meningiomas ($p<0.001$). The area under the curve (AUC) of ADC value for differentiating schwannomas from meningiomas was 0.957, and the sensitivity and specificity were 92% and 89%, respectively ($p<0.001$). The AUC of ADC ratios was 0.932, and the sensitivity and specificity were 92% and 79%, respectively ($p<0.001$).

Conclusion: The ADC value and ADC ratios may helpful in discriminating schwannomas and meningiomas. Although diagnosis of schwannoma and meningioma is based on typical imaging features, ADC value and ratio can provide a clue for a discrepancy in controversial cases.

Keywords: Apparent diffusion coefficient, diffusion-weighted imaging, vestibular schwannoma, meningioma

Öz

Amaç: Posterior fossa schwannom ve menenjiyomlarının ayrımında görünür diffüzyon katsayısı (ADC) değerlerinin tanısal etkinliğini değerlendirmektir.

Yöntem: Posterior fossa ekstraaksiyal lezyonu tanısı ile manyetik rezonans görüntüleme (MRG) elde edilen 55 hasta retrospektif değerlendirildi. Tümörler konvansiyonel MRG bulgularına göre ayrıldı. İki radyolog tarafından, tümörden ve referans değer olarak karşı serebellar parankimden ilgilenilen bölge kullanılarak elde edilen ortalama ADC ölçümleri ile ADC oranları hesaplandı. Schwannom ve menenjiyomların ortalama ADC ölçümleri ile ADC oran farklılıkları istatistiksel olarak analiz edildi.

Bulgular: Hastaların %52,7'si erkek, %47,3'ü kadın olup yaş ortalaması 53,4 idi. Konvansiyonel MRG özelliklerine göre lezyonların 29'u schwannom, 26'sı menenjiyom olarak yorumlandı. Schwannom ve menenjiyomların ortalama ADC değerleri ($\times 10^{-3}$ mm^2/s) sırasıyla 1,087±0,224 ve 0,729±0,130; ADC oranları ise 1,56±0,34 ve 1,08±0,17 bulundu. Schwannomların ortalama ADC değerleri ve ADC oranları menenjiyomlardan anlamlı derecede yüksekti ($p<0,001$). Schwannom ve menenjiyom ayrımında ortalama ADC değeri için ROC eğrisi altında kalan alan 0,957, duyarlılık %92, özgüllük %89 saptandı ($p<0,001$). Schwannom ve menenjiyom ayrımında ADC oran değeri için ROC eğrisi altında kalan alan 0,932, duyarlılık %92, özgüllük %79 saptandı ($p<0,001$).

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Öz

Sonuç: Schwannom ve menenjiyomların ayrımında ortalama ADC ve ADC oran değerleri yardımcı olabilir. Schwannom ve menenjiyom ayırıcı tanısı tipik görüntüleme özellikleri ile yapılabilse de tartışmalı olgularda ortalama ADC ve ADC oran değerleri tanıya yönelik ipucu verebilmektedir.

Anahtar Kelimeler: Görünür difüzyon katsayısı, difüzyon ağırlıklı görüntüleme, vestibüler schwannom, menenjiyom

Introduction

Cerebellopontine angle (CPA) is a triangular space containing important neurovascular structures and is the most common location for posterior fossa tumors. Vestibular schwannomas (VS) are the most frequent tumors of CPA account for 70-80%, followed by meningiomas, which comprise 10-15% of all lesions. Clinical presentation depends on size, location, and histologic type of tumor. Radiologists have been well acquainted with conventional MRI findings to differentiate these two lesions. An extra-axial lesion with broad dural base, hyperdensity on non-enhanced computed tomography (NECT) (69%), isointensity or slightly hypointensity to gray matter on T1-weighted images (T1WI), calcification (25%), heterogeneity caused by calcifications and cystic foci, and perifocal edema, herniation into the middle cranial fossa (56%), osteoproliferation are related to the more frequent in meningiomas[1]. Isodensity (64%) on NECT, hyperintensity on T2WI, intense homogeneous enhancement on T1WI, heterogeneity due to intratumoral degenerative and cystic changes, and widening of the porus acusticus are more common with VSs. However, this may be very difficult in cases due to these two histologic types sharing significant overlaps in conventional imaging features.

Diffusion-weighted imaging (DWI) has been reported to help reflect the cellularity and heterogeneity of tumors and is widely used in the differential diagnosis of intracranial neoplasms. In recent years, a few studies have assessed the discriminating ability of DWI in meningiomas and schwannomas in CPA. And preoperative information may influence treatment methods, surgical techniques, and patient outcomes. Therefore, it is also clinically crucial to accurately preoperatively discriminate VSs from meningiomas.

In this study, we aimed to investigate the usefulness of ADC values in distinguishing VSs and meningiomas of CPA.

Materials and Methods

Study Population

This retrospective study was approved by the institutional review board. Ethical approval was obtained from the Ethics Committe of Gazi University (decision no: 867, date: 21.12.2020). Because this is a retrospective study, no informed consent form was acquired. We analyzed 68 consecutive patients who underwent MRI for CPA pathology before stereotactic radiosurgery at our institution between January 2015 and December 2019. Nine patients with a history of surgery or stereotactic radiosurgery were excluded from the study. In addition, four patients were excluded from the study because the conventional MRI findings for meningioma and schwannoma were not typical. We reviewed each patient with respect to age, gender, and DWI MRI findings. All patients underwent conventional brain MRI and DWI. The study includes radiological findings but no other clinical or laboratory results.

A total of 55 patients (29 males and 26 females) were included in our study with a mean age of 53.4±14.54 (range 20-79) years.

MR Imaging

All brain MR exams were performed at a 1.5 T MR imaging scanner (MAGNETOM Aera, Siemens Healthcare, Erlangen, Germany). The protocols of conventional MRI consisted of spin-echo T1WI [repetition time (TR)/echo time (TE), 447 ms/11 ms and T2WI (TR/TE, 4540 ms/113 ms)], and gadolinium (Gd)-enhanced gradient-echo T1WI (TR/TE, 663 ms/17 ms).

DWIs were obtained in the axial plane by echo-planar imaging (EPI sequence) before injection of Gd. The scanning parameters were as follows: TR/TE, 5760 ms /61 ms, field of view, 218x218 mm, slice thickness: 4.5 mm, gap: 5.8 mm, matrix: 164x164 mm. Two b values (0 and 1000 s/mm^2) were used in the 3 orthogonal directions.

Image Analysis

All MRI data were transferred to a workstation and analyzed by two experienced radiologists (with 9 and 10 years of clinical experience in neuroradiology) in consensus. Tumor size, morphology, and concomitant pathologies were evaluated based on standard MRI sequences. The ADC map was analyzed with commercial software (Neuro 3D; Siemens

Healthcare), which was available in the workstation (Syngo MR B17 Version, Siemens, Germany). To measure values, circular ROIs with a diameter of about 1 cm (100-130 mm^2) were placed in the solid tumor area while avoiding cystic and hemorrhagic areas (Figures 1, 2). At least three ROI measurements were taken, with the average recorded. In addition, circular region of interest (ROI) with a diameter of approximately 1 cm was positioned in the contralateral cerebellar hemisphere to extract standard ADC values. The ADC ratio was calculated as the ADC value of the tumor divided by the standard ADC.

Statistical Analysis

All statistical analysis was performed in IBM SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as means with their standard deviation. Categorical variables were assessed in terms of numbers and percentages. The ADC value and ADC ratio for VSs and meningiomas were compared using an independent t-test. The diagnostic performance of the ADC values, and ADC ratios to discriminate VSs and meningiomas was evaluated using the area under the receiver operating characteristics (ROC) curve (AUC). The Youden J index was used to assess the maximum sensitivity and specificity. P-value <0.05 was considered statistically significant.

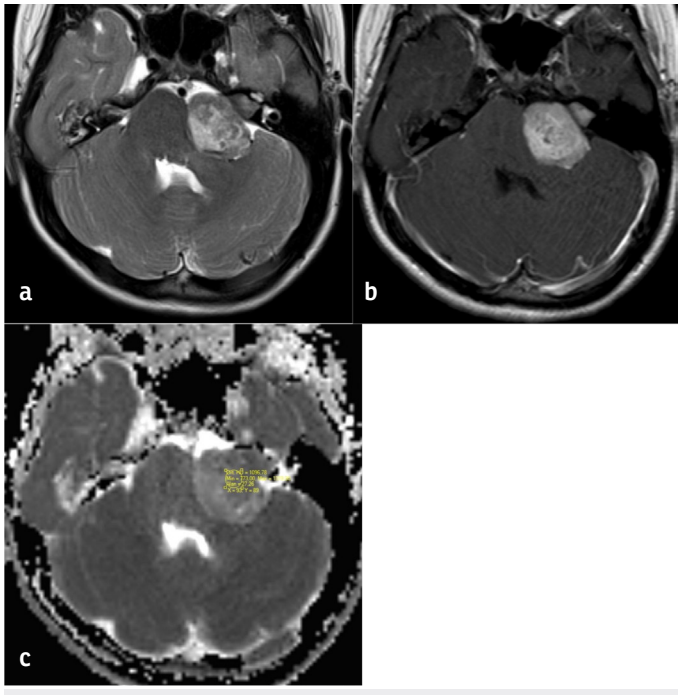

Figure 1. Eighteen-year-old girl with a known diagnosis of neurofibromatosis type 2 came for follow-up. Bilateral cerebellopontine angle lesions extend into the internal acoustic canal. **a)** Axial T2 weighted and contrast-enhanced T1 weighted image, **b)** Shows occupying masses in bilateral CPA. Hyperintense on T2WI and. showing heterogenous post-contrast enhancement, with T1WI+C (note vivid enhancement in left located lesion). MRI findings are suggestive of bilateral IAC schwannomas, **c)** Mean ADC values within the solid parts of the lesion are about 1.09×10^{-3} mm^2/s

MRI: Magnetic resonance imaging, ADC: Apparent diffusion coefficient, T1WI: T1-weighted images, T2WI: T2-weighted images, CPA: Cerebellopontine angle

Results

Socio-demographic features, mean ADC, and ADC ratio are given in Table 1. Twenty-nine patients were diagnosed with VS, and 26 patients were diagnosed with meningioma depending on typical MRI appearance using conventional MRI. In the VS group, 12 (41.4%) were female and 17 (58.6%)

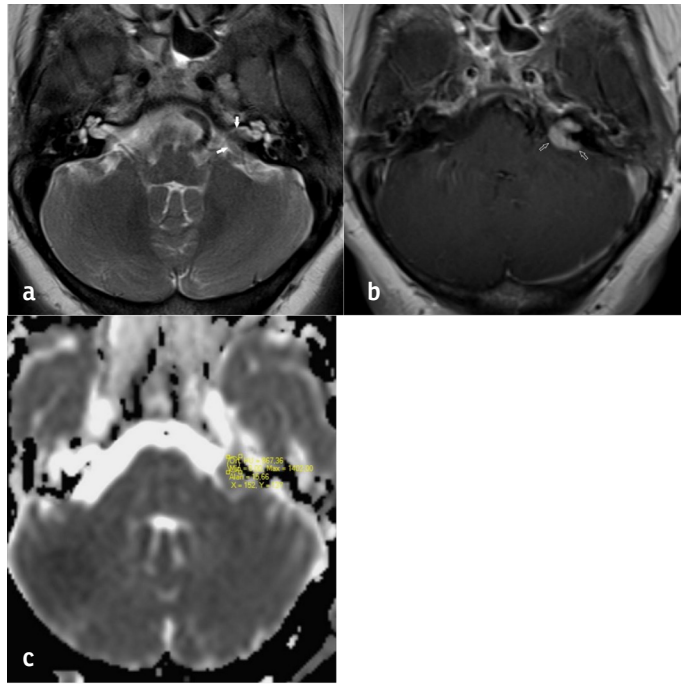

Figure 2. Fifty eight-year-old male with posterior fossa mass. **a)** Axial T2WI demonstrating a broad-based extra-axial mass with iso-intensity located in left CPA (arrows), **b)** shows homogeneous marked enhancement on contrast-enhanced T1WI. MRI findings are indicative of meningioma (arrows), **c)** ADC maps show relatively restricted diffusion, with mean ADC values within the lesion measured about 0.8×10^{-3} mm^2/s

MRI: Magnetic resonance imaging, ADC: Apparent diffusion coefficient, T1WI: T1-weighted images, T2WI: T2-weighted images, CPA: Cerebellopontine angle

were male with a mean age of 54.03±16.87 years (range 20-79 years). Among 29 patients with meningioma, 14 (53.8%) were female and 12 (46.2%) were male, with a mean age of 51.92±11.63 years (range 30-79 years).

The mean ADC values of schwannomas and meningiomas were 1.087±0.224 ($\times10^{-3}$ mm^2/s) and 0.729±0.130 ($\times10^{-3}$ mm^2/s), respectively. Mean ADC ratios were 1.56±0.34 for schwannomas and 1.08±0.17 for meningiomas. The mean ADC values and ADC ratios of schwannomas were significantly higher than those of meningiomas (p<0.001).

Table 2 shows the diagnostic performance of ADC and ADC ratios for differentiating schwannomas from meningiomas, and Figure 3 shows using ROC curves.

The AUC of ADC value for differential diagnosis between schwannomas and meningiomas was 0.957 (p<0.001). For the ADC cut-off value of 0.89×10^{-3} mm^2/s, the sensitivity and specificity were 92% and 89%, respectively. The lesions with ADC values more than 0.89×10^{-3} mm^2/s can be diagnosed as schwannoma, lower than 0.89 ($\times10^{-3}$ mm^2/s) can be diagnosed as meningioma.

The AUC of ADC ratios for differential diagnosis between schwannomas and meningiomas was 0.932 (p<0.001). For the ADC ratio cut-off value of 1.28, the sensitivity and specificity were 92% and 79%, respectively. The lesions with a higher ADC ratio (>1.28) can be diagnosed as schwannoma; with lower ADC ratio values (<1.28) can be diagnosed as meningioma.

Table 1. Demographic features and ADC values

Demographic	Number	Percent
Gender		
Male	29	52.7
Female	26	47.3
Lesions		
Schwannoma	29	52.7
Meningioma	26	47.3
	Mean	**Standard deviation**
Age	53.04 (20-79)	14.54
ADC value ($\times10^{-3}$ mm^2/s)		
Schwannoma	1.087	0.224
Meningioma	0.729	0.130
ADC ratio		
Schwannoma	1.56	0.34
Meningioma	1.08	0.17

ADC: Apparent diffusion coefficient

Table 2. Diagnostic performance of ADC value and ADC ratio for differentiating vestibular schwannoma from meningioma located in the cerebellopontine angle

	AUC	p-value	Cut-off	Sensitivity (%)	Specificity (%)
ADC value	0.957	<0.001	<0.890	92.31	89.66
ADC ratio	0.932	<0.001	<1.28	92.31	79.31

ADC: Apparent diffusion coefficient, AUC: Area under the curve

Discussion

VS (85%) and meningiomas (10-15%) constitute approximately 90-95% of all CPA tumors[2,3]. Although frequently distinguished by conventional MRI characteristics or indirect signs of lesions, lack of typical appearance, uncommon findings, and small lesions can pose a diagnostic challenge. As a result, additional imaging modalities, such as DWI, are required to aid in the diagnosis and differentiation of CPA tumors. The present study aims to evaluate the role of DWI in the discrimination of CPA VS and meningiomas.

DWI is an MRI technique that enables the evaluation of molecular water movement in the tissue. Molecular diffusion patterns reflect noninvasively microscopic tissue architecture, higher cellularity, tissue disorganization, and

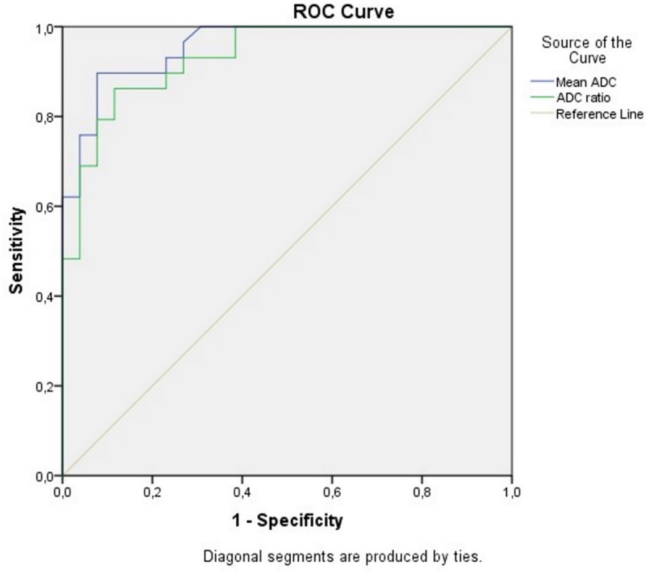

Figure 3. ROC curves of the mean ADC and ADC ratio for discrimination of VSs from meningiomas

ROC: Receiver operating characteristics, ADC: Apparent diffusion coefficient, VS: Vestibular schwannomas

type of cells. In previous studies, ADC values were found to strongly correspond to different tumor type distinctions[4,5]. Tumors with a higher nuclear to cytoplasmic ratio tend to show higher DWI signals and lower ADC values[4]. Besides reduced extracellular fluid compartment inside tumor cell plays a role in limiting diffusion and contributes to lowering of ADC values.

A study by Pavlisa et al.[6] which compared schwannomas and typical, atypical meningiomas, reported mean ADC values as 1.33, 0.93, and 0.91×10^{-3} mm^2/s, respectively, and found that ADC values in VS were significantly different from the ADC values of both the typical and atypical meningiomas. Similarly, the mean ADC values in VSs (1.087±0.224×10^{-3} mm^2/s) in our series were significantly higher than in meningiomas. In our series, the mean ADC values were less than comparable with literature results probably due to imaging protocol characteristics or ROI analysis method from the solid tumor area while avoiding cystic and hemorrhagic areas. Previous reports revealed that ADC values were higher in larger schwannomas with the predominance of Antoni B-cell or microcystic changes[7,8]. Srinivasan et al.[9] demonstrated lower ADC in low T2 lesions (0.739×10^{-3} mm^2/s), while higher ADC in (2.033×10^{-3} mm^2/s) in cystic schwannomas. In contrast, Sener[10] found mean ADC values as 1.42±0.17×10^{-3} mm^2/s in solid VSs. We have delineated the solid portion ROIs, as Sener[10] did. When Schwannomas are constituted predominantly of Antoni B areas, they are formed of microcystic spaces filled with rich myxoid matrix and hypocellular areas. When they are formed predominantly of Antoni A, they are packed with densely cellular areas. The discrepancies of mean ADC in the literature may stem from differences in tumor sizes, cellularity, and tumor matrix or different scanners.

As mentioned above, in the present study, the mean ADC values of meningiomas (0.729±0.130×10^{-3} mm^2/s) were significantly different from VSs. The majority of meningiomas (90-95%) corresponded to benign World Health Organization grade I (typical) tumors. In our study meningiomas had a typical radiological appearance. Lack of typical conventional MRI findings mostly suggests histologically grade II (atypical) or grade III (anaplastic) meningiomas. Numerous studies investigated DWI features of meningiomas[11-13]. The decreased water diffusivity in meningiomas may be the result of the high cellular density and collagen-rich matrix of the tumor cells. In the present study, in accord with previous studies meningiomas had lower ADC values (0.729)[11-14]. Yamasaki et al. [11] also reported significantly lower ADC values in meningiomas (1.036±0.270×10^{-3} mm^2/s), compared to the schwannomas (1.384±0.140×10^{-3} mm^2/s). But ADC derived from a solid portion can underestimate the tumor heterogeneity in meningiomas. A range of mean ADC values varied slightly wider in schwannomas than in meningiomas. A possible explanation for this might be that the homogeneous structure of meningiomas in our sample with no calcification or cystic space.

The intra-lesion heterogeneity, observer variability of the ROI analysis, and differences in diffusion patterns in histological types based on cellularity result in a wide range of ADC values. In recent studies on other clinical applications of DWI, to decline the variability in different DWI parameters, improve the repeatability, reproducibility of ADC measurements across different scanners, ADC ratios are considered to be superior to ADC values[14-16]. Only a few studies have evaluated ADC ratios in evaluating meningiomas, schwannomas, or differentiating one from another. Khedr et al.[17] included 31 patients with meningiomas and found that atypical meningiomas had a lower ADC ratio value (0.61) when compared to typicals (1.21). By focusing on the ADC characteristics of typical/atypical meningiomas and schwannomas, Pavlisa et al.[6] found the ADC ratio of schwannomas (1.67) was also significantly different from the typical (1.19) and atypical (1.15) meningiomas, but not in between different meningiomas. Our results suggested that the cut-off values for ADC ratio above 1.28 might enable us the separation of schwannomas from the meningiomas with a sensitivity of 92.31% and 79.31% specificity.

Study Limitations

The major limitation was the retrospective nature of our study. Secondly, the study had a small lesion population only located at CPA; larger series are needed to reinforce the effectiveness of ADC values found in this paper. Thirdly, an ROI from solid portions of tumors was drawn for assessment, however, schwannomas are likely to show heterogeneity due to cystic degeneration and this may also limit the representativeness of our sample. Finally, the study was based on the CPA tumors undergoing radiosurgery with typical conventional MRI findings, therefore lack of biopsy-proven diagnoses resulted in an inability to compare our findings with the histopathologically.

Conclusion

Our results show that combination with set threshold values for the mean ADC and ADC ratios may improve

characterization and provide additional ability for a more confident differentiation between VS and meningiomas. Also, DWI may serve as a promising alternative for contrast-enhanced imaging in the discrimination of CPA lesions histologic types.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Ethics Committe of Gazi University (decision no: 867, date: 21.12.2020).

Informed Consent: Since this is a retrospective study, no informed consent form was acquired.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: H.Ö, A.Y.O., Concept: H.Ö, M.Y., Design: M.Y, H.Ö., Data Collection or Processing: M.Y., Analysis or Interpretation: H.Ö., A.Y.O., Literature Search: M.Y., A.Y.O., Writing: M.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

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