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ADC is not reliable in determinating subtypes of meningiomas

Research Article

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Abstract: Objective. To verify the reliability of apparent diffusion coefficient (ADC) measurements in determining subtypes of meningiomas. Material and methods. Thirty patients (20 women and 10 men; average age, 53±15 years) with meningiomas were prospectively studied using DWI with b values of 0 and 1000. ADC values of the neoplastic tissue were obtained as the mean of measurements from three regions of interests within the mass and compared with histologic subtypes using ANOVA test (SPSS16). Results. The meningothelial subtype was found in 15 (50%) patients, fibroblastic in 10 (33.33%) patients and cystic in 5 (16.67%) patients. All meningiomas belonged to the WHO Grade 1 – benign meningiomas. There was no significant statistical difference between meningothelial, fibroblastic and cystic meningiomas when considering mean ADC values (0.000411+/-0.000066 mm2/s vs. 0.000750+/-0.001045 mm^2/s vs. 0.000688+/-0.000063 mm^2/s ($p>0.05$). Perifocal edema was present only with fibroblastic meningioma with mean ADC 0.000683 mm^2/s. The ADC of the cystic component was statistically significantly higher in cystic meningeomas (0.001283 mm^2/s) compared with fibroblastic (0.000224 mm^2/s) and meningothelial meningiomas (0.000088 mm^2/s) ($p<0.001$). The ADC of meningiomas was higher compared with contralateral healthy brain tissue (0.000642 mm^2/s vs. 0.000404 mm^2/s; n.s). Conclusion. ADC measurement do not seem reliable in identifying histological subtypes of Grade I meningiomas.

Keywords: *Diffusion Weighted Imaging • ADC • Meningiomas*

1. Introduction

Meningiomas, mostly benign tumours originating from the arachnoid cap cells [1], present 13-26% of all intracranial tumours [2]. They are more common in older age and in females [1]. Although they are generally benign tumors, up to 10% of meningiomas are atypical or malignant [3]. MRI is a key modality not only for lesion diagnosis, but also to evaluate the extension, type and grade of the tumor. Advanced MRI techniques such as DWI provide physiologic information that complements the anatomic information available with conventional MRI [4]. DWI uses strong magnetic field gradients to make the MRI signal intensity sensitive to the molecular motion of water [5].

The aim of our study was to verify the reliability of ADC measurements in determining subtypes of meningiomas.

2. Material and methods

A prospective study involved a group of 30 patients with histologically proven intracranial meningiomas in the

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period 2005-2010. No patients had begun corticosteroid treatment or radiation therapy, and none had previous brain biopsy at the time of MRI. Tumors with large calcifications, hemorrhages, or both were excluded. Thirty patients (20 women and 10 men; average age, 53 ±15 years) with meningiomas were prospectively studied using routine magnetic resonance imaging (MRI) and diffusion-weighted imaging (DWI) with a single-shot gradient-echo echo-planar pulse sequence (6000/100 [TR/TE]) and b values of 0 and 1000. The examinations were performed in all patients up to seven days before surgery according to the standard protocol with the following sequence: axial T2-weighted, DWI, and axial spin-echo T1-weighted imaging (T1WI) performed before and after intravenous administration of 0.1 mmol/kg body weight of gadopentetate dimeglumine (Gadovist; Schering, Berlin, Germany). All MRI studies were performed with a 1.5T unit (Avanto; Siemens, Erlangen, Germany). ADC values of the neoplastic tissue (avoiding calcifications and cystic or necrotic areas) were obtained as the mean of measurements from three regions of interests within the mass. Signal characteristics on routine MR and DWI were compared with the histopathologic findings after resection by using World Health Organization criteria. Two neuroradiologists performed qualitative visual inspections of DW images and ADC maps with consensus reading using softwear DP Tools. On DWI and ADC maps, each lesion was categorized as being predominantly hyperintense, isointense, or hypointense relative to the cortex. Three circular regions of interest (ROIs) with diameter 1 cm were placed centrally within the largest solid-enhancing area of all meningiomas and peritumoral area if edema was present.

Comparison of the ADC values between patients with different histological diagnoses was performed by ANOVA test (SPSS16). The comparison of the tumor presentation on spin-echo (SE) sequences between patients with different histological diagnoses was performed by Fisher exact probability test of the null hypothesis (Fisher's exact test). *P* values less than .05 were considered to indicate statistically significant differences.

3. Results

MRI was performed in 30 patients with intracranial meningiomas. The study included 20 (66.66%) women and 10 (44.44%) men, with the female predominance in incidence M:F=1:2. The youngest patient was 29 years old and the oldest 73 years. Meningiomas occur in the middle decades of life, with mean age 53±15 years.

From the total number of patients (30), meningothelial meningiomas were diagnosed in 15 (50%) patients. Fibroblastic meningiomas were found in 10 (33.33%) and cystic meningiomas in 5 (16.67%) patients (Table 1). Meningothelial meningeomas showed tendency to appear in older and cystic meningeomsa in younger patients (Table 2).

The values of ADC in the solid part of different histological types of meningioma are shown in Table 3. The mean ADC value of meningothelial meningiomas (0.000411 ± 0.000066 mm^2/s) was lower than both mean ADC value of fibroblastic meningiomas (0.000750± 0.001045 mm^2/s) and anaplastic meningioma (0.000688 ± 0.000063 mm^2/s). The mean ADC value of fibroblastic meningiomas (0.000750 ± 0.001045 mm^2/s) was higher than both ADC values of meningothelial meningiomas (0.000411±0.000066 mm^2/s) and ADC cystic meningiomas (0.000688 ± 0.000063 mm^2/s). The mean ADC value of cystic meningiomas (0.000688 ± 0.000063 mm^2/s) was higher than mean ADC value of meningothelial meningiomas (0.000411±0.000066 mm^2/s) and lower than the mean ADC value of fibroblastic meningiomas (0.000750 ± 0.001045 mm^2/s).

Table 1. Distribution of histopathological type of meningiomas

Histopathological diagnosis	Sex		Total
	Woman	Man	
Meningothelial meningiomas	10 (66.66%)	5 (33.34%)	15 (50%)
Fibroblastic meningiomas	7 (70%)	3 (30%)	10 (33.33%)
Cystic meningiomas	3 (60%)	2 (40%)	5 (16.67%)
Total number of meningiomas	20 (66.66%)	10 (44.44%)	30 (100%)

Table 2. Distribution of patients compared to histopathological diagnosis and age

Histopathological diagnosis	Age				
	Xsr	SD	Med	Min	Max
Meningothelial meningiomas	64.00	6.25	62.00	59.00	71.00
Fibroblastic meningiomas	48.67	17.05	48.00	26.00	72.00
Cystic meningiomas	46.00	.	46.00	46.00	46.00
Total number of meningiomas	53.00	15.11	54.00	26.00	72.00

Table 3. The value of ADC (mm^2/s) of the solid part of meningeoma in comparison with histopathological diagnosis.

Histopathological diagnosis	ADC				
	Xsr	SD	Med	Min	Max
Meningothelial meningiomas	0.000411	0.000066	0.000380	0.000350	0.000540
Fibroblastic meningiomas	0.000750	0.001045	0.000512	0.000224	0.004900
Cystic meningiomas	0.000688	0.000063	0.000672	0.000635	0.000758
Total number of meningiomas	0.000642	0.000816	0.000480	0.000224	0.004900

Table 4. The value of ADC (mm^2/s) in peritumoral brain tissue in comparison with histopathological diagnosis.

Histopathological diagnosis	Parameter				
	Xsr	SD	Med	Min	Max
Meningothelial meningiomas	0.000000	0.000000	0.000000	0.000000	0.000000
Fibroblastic meningiomas	0.000683	0.000316	0.000812	0.000000	0.000910
Cystic meningiomas	0.000000	0.000000	0.000000	0.000000	0.000000
Total number of meningiomas	0.000410	0.000418	0.000376	0.000000	0.000910

Table 5. The value of ADC (mm^2/s) in meningiomas in comparison with healthy brain tissue

	Parameter				
	Xsr	SD	Med	Min	Max
Meningiomas	0.000642	0.000816	0.000480	0.000224	0.004900
Normal tissue	0.000404	0.000059	0.000420	0.000276	0.000501

ADC values in peritumoral brain tissue are shown in Table 4. The ADC of the peritumoral brain tissue around fibroblastic meningiomas (0.000683 ± 0.000316 mm^2 /s) was higher than in meningothelial meningioma (0.000000 ± 0. 000.000mm^2/s) and cystic meningioma (0.000000 ± 0.000000 mm^2 /s), but it was not statistically significant. The values of ADC of meningiomas in comparison with healthy brain tissue are shown on Table 5. ADC of meningeomas was higher comparing with contralateral healthy brain tissue (0.000642 mm^2/s vs. 0.000404 mm^2/s; n.s)

4. Discussion

DWI is currently the only MRI technique that provides information on water diffusion and involves the use of phase-defocusing and phase-refocusing gradients to allow evaluation of the rate of microscopic water diffusion within tissues [6]. The magnitude and direction of diffusion of tissue water depend on the permeability and spacing of diffusion barriers, the viscosity of the suspending medium, and the duration of observation [7].

ADC values of biological tissue are determined by many factors. The motion of the protons is restricted by barriers such as membranes, organelles, cytoskeleton, and macromolecules inside different tissue compartments. Also, the size and number of mobile protons in these compartments can vary [5]. For brain tumors, cellularity likely plays an important role. With higher diffusivity found in the extracellular volume, the increase of intracellular space due to highly cellular tissue is coupled with a decrease of the ADC. Higher cellularity in recurrent neoplasm would contribute to the lower ADC values [8,9].

DWI has been considered a means to characterize and differentiate morphologic features, including edema, necrosis, and tumor tissue by measuring differences in ADC caused by water proton mobility alterations [7,10]. These differences are thought to result from both changes in the balance between intracellular and extracellular water and changes in the structure of the two compartments. DWI uses strong magnetic field gradients to make the MRI signal intensity sensitive to the molecular motion of water. The information provided reflects the viability and structure of tissue on a cellular level [5]. The utility of DWI and ADC mapping in the preoperative diagnosis of brain tumors has been examined by several groups with respect to: assessing cellularity or grade; distinguishing enhancing from non-enhancing areas, tumor from perifocal vasogenic edema, or viable tumor from necrosis; or predicting tumor response to treatment [11]. There appears to be a correlation between the ADC on the one hand and tumor cellularity and tumor grade on the other [12]. Published data on intracranial tumours indicate that high ADC values were attributable to low cellularity, necrosis or cysts, and lower values to dense, highly cellular tumour [7].

Filippi et al. found that the calculation of diffusion coefficient can reliably predict histopathologic features of meningiomas before surgery [13]. The signal intensity of meningiomas on DW images is variable (hyper-, iso-, or hypointense). Most benign meningiomas are isointense on DW images and ADC maps [13,14]. In the study of Filippi et al. [13] 23% of benign meningiomas (three of 13) were slightly hyperintense while four malignant meningiomas had markedly increased signal intensity on DWI, decreased signal intensity on ADC maps, and low ADC values. Hyperintensity on DWI and reduced ADC values correlate with the histopathology of the meningioma [10]. According to Kono et al. [8], the ADC is not indicative of the histologic subtype of meningiomas. Fillipi et al. [13] reported that all of the malignant or atypical meningiomas had markedly increased signal on DWI, hypointense signal on the ADC maps, and extremely low diffusion constants indicative of marked restriction of water diffusion. All of benign meningiomas had imaging characteristics suggestive of benign disease, which included homogeneous signal intensity similar to that of gray matter, intense homogeneous enhancement (no cystic/necrotic/hemorrhagic foci), smooth and distinct margins, and no evidence of brain invasion. According to the study of Santenelli et al. [15], DWI and ADC measurement do not seem reliable in grading meningiomas or identifying histological subtypes. ADC values did not differ significantly among meningioma subtypes although a nearly significant difference was found between meningothelial and transitional meningioma. According to Kono et al. [8], the ADC is not indicative of the histologic subtype meningiomas. Sanverdi et al. [16] has reported there is no existence of any additional value of the DW MR imaging to improve the diagnosis. Therefore, DW MR imaging and ADC measurements do not seem reliable in grading, and differentiating subtypes of meningiomas. Hence, these parameters should not be recommended as guidance for surgical/treatment planning and patient counseling. We found that the ADC may not be predictive of the degree of malignancy in meningiomas or of their histologic subtype. Provenzale et al. [17] reported that ADC values did not differ significantly among meningiomas and contralateral healthy brain tissue.

5. Conclusion

According to our study, ADC measurement do not seem reliable in identifying histological sub-types of Grade 1 meningeomas.

Conflict of interest statement

Authors state no conflict of interest.

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