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DIAGNOSTIC CAPABILITIES OF DIFFUSE-WEIGHTED MAGNETIC RESONANCE IMAGING IMAGING IN BRAIN MENINGIOMAS

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Summary

Relevance: The method of diffusion-weighted magnetic resonance imaging allows you to get information about the structural state of various tissues and organs. Currently, the method of diffuse-weighted images and the measured diffusion coefficient have not received widespread clinical use, with the exception of scientific works on the study of brain ischemia, demyelinating diseases, and injuries.

The aim of the work is to compare the values of the measured diffusion coefficient of various forms of meningiomas and assess the possibilities of applying the methods of diffusion-weighted magnetic resonance imaging in the differential diagnosis of malignancy of brain meningiomas.

Material and methods: Research method - continuous sample. Magnetic resonance tomograms were analyzed using diffusion imaging programs and calculating the measured diffusion coefficient of 53 patients (32 of them women, 21 men) who were examined at the Semei Consultative and Diagnostic Center and the Center for Nuclear Medicine and Oncology. Semey, in the Center for Oncology and Surgery Ust-Kamenogorsk, for the period 2008 - 2014.

Statistical data processing was performed using Microsoft Excel 2010. All measurements were checked for normality using the Kolmogorov – Smirnov test. The data obtained are evaluated using descriptive statistics methods. A comparative analysis of the measured diffusion coefficient values was performed using the Mann-Whitney U-test.

Results. When analyzing the average values of the measured diffusion coefficient, it was established for all types of meningiomas that the average value of the measured diffusion coefficient was determined: for meningiomas, MI was 1399.5 ± 154.6 mm^2/s; for meningiomas MII - 1136.2 ± 150 mm^2/s; for meningiomas MIII - 706 ± 73.4 mm^2/s.

No significant differences were found when comparing the measured diffusion coefficient of meningiomas M1 and M2 ($p = 0.723$). But when comparing the measured diffusion coefficient of meningiomas M1 and M3, as well as M2 and M3, significant differences were found (M1 / M3 - $p = 0.007$, M2 / M3 - $p = 0.0010$).

Conclusions: The technique of magnetic resonance imaging using diffusion imaging programs and calculating the measured diffusion coefficient can be used as an additional non-invasive method for the differential diagnosis of intracranial meningiomas when conducting magnetic resonance studies.

Keywords: meningioma, diffusion-weighted MRI, measured diffusion coefficient, diffusion-weighted image

Резюме

ДИАГНОСТИЧЕСКИЕ ВОЗМОЖНОСТИ ДИФФУЗНО-ВЗВЕШЕННЫХ ИЗОБРАЖЕНИЙ МАГНИТНО-РЕЗОНАНСНОЙ ТОМОГРАФИИ ПРИ МЕНИНИНГИОМАХ ГОЛОВНОГО МОЗГА

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Актуальность: Методика диффузионно-взвешенной магнитно-резонансной томографии позволяет получить информацию о структурном состоянии различных тканей и органов. В настоящее время метод диффузно-взвешенных изображений и измеряемого коэффициента диффузий не получили широкого клинического применения, за исключением научных работ по исследованию ишемии мозга, демиелинизирующих заболеваний, травм.

Цель работы – сопоставить значения измеряемого коэффициента диффузий различных форм менингиом и провести оценку возможностей применения методики диффузионно-взвешенной магнитно-резонансной томографии в дифференциальной диагностике злокачественности менингиом головного мозга.

Материал и методы: Метод исследования – сплошная выборка. Были проанализированы результаты магнитно-резонансных томограмм с применением программ диффузионного изображения и расчетом измеряемого коэффициента диффузии 53 пациентов (из них 32 женщины, 21 мужчин), которые проходили обследования в Консультативно-диагностическом Центре г. Семей и Центре ядерной медицины и онкологии г. Семей, в Центре онкологии и хирургии г.Усть-Каменогорск, за период 2008 - 2014 гг.

Статистическая обработка данных проведена с помощью программного обеспечения Microsoft Excel 2010. Все измерения проверены на нормальность с помощью теста Колмогорова–Смирнова. Полученные данные оценены с помощью методов описательной статистики. Сравнительный анализ значений измеряемого коэффициента диффузии выполнен с помощью U-теста Манна-Уитни.

Результаты. При анализе средних значений измеряемого коэффициента диффузии установлено для всех типов менингиом, было установлено, что среднее значение измеряемого коэффициента диффузии: для менингиом MI составило 1399,5 ± 154,6 мм^2/с; для менингиом MII – 1136,2 ± 150 мм^2/с; для менингиом MIII – 706 ± 73,4 мм^2/с. Значимых различий при сравнении измеряемого коэффициента диффузии менингиом М1 и М2 не выявлено (p=0,723). Но при сравнении измеряемого коэффициента диффузии менингиом М1 и М3, а так же М2 и М3 были выявлены значимые различия (М1/М3 - p =0,007, М2/М3 – p=0,0010).

Выводы: Методика магнитно-резонансной томографии с использованием программ диффузионного изображения и расчетом измеряемого коэффициента диффузии может быть использована в качестве дополнительного неинвазивного метода дифференциальной диагностики интракраниальных менингиом при проведении магнитно-резонансных исследований.

Ключевые слова: *менингиомы, диффузионно-взвешенная МРТ, измеряемый коэффициент диффузии, диффузионно-взвешенное изображение*

Түйіндеме

МИДЫҢ МЕНИНГИОМАСЫНЫҢ МАГНИТТІ-РЕЗОНАНСТЫ ТОМОГРАФИЯНЫҢ ДИФФУЗИЯЛЫҚ ӨЛШЕМ БЕЙНЕСІНІҢ ДИАГНОСТИКАЛЫҚ МҮМКІНДІКТЕРІ

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Тақырыптың өзектілігі: Диффузияның өлшенген магниттік-резонансты бейнелеу әдісі түрлі тіндердің және мүшелердің құрылымдық күйі туралы ақпаратты алуға мүмкіндік береді. Қазіргі кезде диффузиялық өлшеу әдісі мен өлшенген диффузия коэффициенті мидың ишемияларын зерттеу, демиелинге ұшыраған аурулар мен жарақаттар туралы ғылыми жұмыстарды қоспағанда кең таралған клиникалық қолданысқа ие болмады.

Жұмыстың мақсаты менингиомалардың әртүрлі нысандарының өлшенген диффузия коэффициентінің мәндерін салыстыру және мидың менигиомаларының қатерлі ісігінің диагностикасында диффузиялық өлшенген магнитті-резонансты бейнелеу әдістерін қолдану мүмкіндігін бағалау болып табылады.

Материалдар мен әдістер: Зерттеу тәсілі- жалпылай өндіру.Магнитті резонанстық томограммалар диффузиялық бейнелеу бағдарламалары бойынша талданды және Семей консультативтік-диагностикалық орталығында, Семей Ядролық медицина және онкология орталығында және Өскемен қаласының онкология және хирургия орталығында, 2008 - 2014 жылдар кезеңінде зерттелген 53 пациенттің (32 әйел, 21 ер адам) өлшенген диффузия коэффициентері есептелді.

Статистикалық ақпаратты өндіру Microsoft Excel 2010 бағдарламасы арқылы жүргізілді. Барлық өлшемдер теста Колмогорова–Смирнова тексеру арқылы дұрыстығы тексерілген. Алынған деректер сипаттама статистика тәсілі арқылы бағаланған. Салыстырмалы талдау мағынасы есептелген коэффицент диффузиясы U-теста Манна-Уитни арқылы орындалған.

Нәтижелері. Менингиоманың барлық түрлері бойынша өлшенген диффузия коэффициентінің орташа мәндерін талдағанда өлшенген диффузия коэффициентінің орташа мәні: MI менингиомалары үшін 1399,5 ± 154,6 мм^2/с болған; MII менингиомалары үшін - 1136,2 ± 150 мм^2/с; MIII менингиомалары үшін - 706 ± 73.4 мм^2/с.

MI және MII менингомалардың өлшенген диффузия коэффициентін салыстыру кезінде маңызды айырмашылықтар табылмады (p = 0,723). Бірақ MI және MIII, сонымен қатар MII және M3 өлшемдерінің диффузия коэффициентін салыстыру кезінде маңызды айырмашылықтар анықталды (MI / MIII - p = 0.007, MII / MIII - p = 0.0010).

Қорытынды: Магнитті резонансты зерттеу кезінде диффузиялық бейнелеу бағдарламаларын қолдану және өлшенген диффузия коэффициентін есептеу әдістемесі магнитті резонансты зерттеу кезінде инкракраниалды менингиомалардын дифференциалды диагностикалаудың қосымша инвазивті емес әдісі ретінде қолданыла алады.

***Негізгі сөздер**: менингиомалар, диффузиялық өлшенген МРТ, өлшенген диффузия коэффициенті, диффузиялық өлшенген бейнелер.*

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Relevance

According to literary data of a number of different authors, meningiomas are one of the most common groups of intracranial tumors and constitute from 18 to 35.8% of all primary brain tumors in adults and second only to neuroectodermal tumors [2, 5, 9, 17, 20, 21]. In addition, meningiomas occupy the first place in terms of occurrence in the group of tumors emanating from the meninges.

Many authors are inclined to believe that an increase in the incidence of brain tumors in general and meningiomas in particular is due to a number of reasons, such as natural aging of the population, the introduction and high availability of diagnostic procedures, such as computed tomography and magnetic resonance imaging, and the frequency of histological evidence even in old age [6].

The distribution of patients with intracranial meningiomas among men and women in different studies varies widely, with a peak incidence of 40-60 years [7, 15]. The fact that cerebral meningiomas are more often affected by women was also noted by Cushing. Thus, according to research data from a number of authors, the ratio of men and women was from 1: 1.4 to 1: 2.8 in favor of women [8, 24]. The data published in the American Cancer Base of the Central Brain Tumor Register of the United States, say that the incidence of intracranial meningiomas in women is 2.2 times higher than in men, and averages 4.44 cases of men to 10.02 incidence of women per 100 000 population [20, 21].

According to a number of studies, it can be said that the increase in the incidence of cerebral meningiomas among women is about three times as compared with men - 3.3: 1 [16].

In the age groups, the incidence of meningiomas is also unevenly distributed. According to a study conducted by M. Rohringer, it can be noted that the peak incidence in men falls on the 50-60-year age group, and in women - on the 60-70-year group, with a frequency of 6-9.5 cases per 100000 population [18]. According to other researchers, the incidence of meningiomas occurs most, regardless of the patient's gender, in age groups from 40 to 70 years old - approximately 80% of all cases [2]. In their studies I. Baldi et al. noted that the incidence of cerebral meningiomas increases gradually to 89 years, with the peak incidence falling on the 75-89 year old age group, the incidence of which was 22.2 per 100,000 people [6].

Despite the above studies, meningiomas can occur in childhood. According to the American Cancer Base Central Brain Tumor Register of the United States, the incidence in the age group from 0 to 14 years is an average of 0.09 per 100,000 population, and at the age of 85 and older - 48.95 per 100,000 people [20, 21]. According to some authors, about 1% - 2% of meningiomas are found in the age group of 0-16 years, and more often in atypical locations, for example, in the posterior cranial fossa or lateral ventricles [11].

The classification system of brain tumors of the World Health Organization (WHO), including meningiomas, was first published in 1979 in Geneva with the latest edition published in 2016.

The problem in the classification of meningiomas arises from the fact that tumor cells can be represented by mesenchyme cells and epithelial cells. Other mesodermal structures can also give rise to the growth of tumors (for example, hemangiopericytomas or sarcomas).

Pathologic studies of meningiomas, which have been conducted in recent years, were aimed at creating a simplified classification using markers to identify proliferative activity, signs of aggressive growth, and identify malignant forms

Currently, there are three degrees of malignancy (Grade). Each degree of malignancy is divided into several types.

Grade-1 (1st degree of malignancy): benign, slowly growing formations, without atypia, not infiltrating the surrounding tissue. It is 93.5% of all meningiomas. They are characterized by favorable prognosis and low recurrence rate. It includes 9 subtypes: meningotheliomatous, fibrous, transitional, psammomatosis, angiomatosis, microcystic, secretory, with an abundance of lymphocytes, metaplastic. Recurrences of meningiomas of the I degree occur in 7-20% of cases.

Grade-2 (Grade 2): atypical, characterized by more aggressive, faster growth, higher recurrence rates and a less favorable prognosis. Makes up 4.5% of all meningomas. Includes 3 subtypes: clear cell meningioma, chordoid meningioma, atypical meningioma. Grade II meningiomas recur in 30-40% of cases.

Grade-3 (3rd degree of malignancy): malignant neoplasms with poor prognosis, high recurrence rate, aggressively growing and involving surrounding tissues in the process. On average, 1-2% of all meningiomas. Includes 3 subtypes: papillary meningioma, rhabdoid meningioma, anaplastic meningioma. Malignant meningiomas recur in 50-80% of cases and most patients die in the first 2 years after surgery.

Thus, the relevance of highly sensitive diagnosis of intracranial meningiomas is a significant component when conducting their specialized treatment.

The development of imaging techniques such as computed tomography (CT) and especially magnetic resonance imaging (MRI), which appeared in the 60s and 80s of the 20th century, made it possible to make a major breakthrough in the non-invasive study of brain tumors, their influence on the surrounding tissues, improved the possibility of a preliminary assessment of the effectiveness of surgical treatment.

The results of a number of studies indicate that magnetic resonance imaging is the preferred research method for diagnosing meningiomas and their subsequent observation [14]. However, the sensitivity of magnetic resonance imaging, taking into account the use of contrast agents, is not comparable with specificity, since many intracranial formations have similar magnetic resonance characteristics. A number of scientific papers that deal with the study of intracranial meningiomas have been published. Often, perifocal tumors, vasogenic edema is defined, more pronounced in anaplastic meningiomas. In some cases, based on standard computed tomography and magnetic resonance studies, it is difficult to make a diagnosis of meningioma unequivocally. Magnetic resonance imaging may be similar to other brain tumors - neuromas, lymphomas, and sometimes even gliomas. With subtentorial localization, in practice, it is often necessary to differentiate meningiomas with neuromas, which is of practical importance for the surgical treatment. Atypical and especially malignant meningiomas often have to be differentiated from intracerebral tumors. In some studies, attempts were made to reveal the diffusion characteristics of meningiomas in comparison with gliomas.

At the same time, the routine study protocols used in magnetic resonance imaging make it possible to evaluate only the anatomy of normal tissues and pathological structures. With various damaging effects on the substance of the brain, such as ischemic damage, tumor growth, demyelination, and others, a number of pathological processes that are interconnected develop. It should be noted that one of the processes by which the degree of tissue damage can be assessed is the diffusion of water molecules in the extracellular and intracellular space. Evaluation of these effects served as the basis for using nuclear magnetic resonance as a tool for quantifying the diffusion coefficient of water molecules - the diffuse-weighted image (DWI) method of MRI.

Currently, the method of diffuse-weighted images and the apparent diffusion coefficient (ADC) are not widely used in clinical practice, with the exception of scientific studies on brain ischemia, demyelinating diseases, brain injuries and glial tumors. In some papers, the data obtained from diffusion-weighted images and the values of the measured diffusion coefficient differed for the same diseases or had cross-values for various diseases [4].

According to researchers, diffusion-weighted magnetic resonance imaging and the measured diffusion coefficient are necessary for the early diagnosis of acute ischemic strokes, informative in the differential diagnosis of brain tumors and visualization of demyelinating processes [10, 25]. It has been established that the difference between malignant and benign tumors lies in lower values of the measured Apparent Diffusion Coefficient (ADC). Pathological structures with a measured diffusion coefficient lower than 1000 × 10-6 mm^2/s suggest the malignant nature of such formations [1, 25]. However, there is evidence that a number of benign growths may also have DWI values similar to malignant tumors and have low values of the measured diffusion coefficient [13, 25, 26]. Some authors describe the relationship between the value of the measured diffusion coefficient, histological and immunohistochemical parameters of meningiomas [18]. It is important to correctly assess the degree of malignancy and the proliferative potential of these tumors at the stage of neuroimaging research.

Thus, the technique of diffusion-weighted magnetic resonance imaging with the construction of diffusion-weighted images and the calculation of the measured diffusion coefficient can be used as a marker for the differential diagnosis of intracranial meningiomas and predict the effectiveness of their treatment.

In our study, we set **the goal** to compare the values of the measured diffusion coefficient of various forms of meningiomas and to assess the possibilities of using the methods of diffusion-weighted magnetic resonance imaging in the differential diagnosis of brain meningio malignancy. No similar studies have been conducted on the territory of the East Kazakhstan region, which is also of certain scientific interest.

Material and methods

A continuous sampling was made among patients who are registered at the Semei Consultative and Diagnostic Center and the Semey Nuclear Medicine and Oncology Center, at the Ust-Kamenogorsk Center for Oncology and Surgery in the East Kazakhstan region of the Republic of Kazakhstan. Based on a continuous sample, the results of magnetic resonance tomograms were analyzed using diffusion imaging programs and calculating the measured diffusion coefficient of 53 patients (32 of them are women, 21 are men) who were examined at the Semey Consultative and Diagnostic Center and Oncology, Semey, at the Center for Oncology and Surgery, Ust-Kamenogorsk, for the period 2008 - 2014. The average age of female patients was 55.8 ± 9.3 years, male - 55.0 ± 8.7 years).

Tomograms (T1-, T2-weighted images and diffusion-weighted images) were obtained using the MAGNETOM ESPREE “SIEMENS” magnetic resonance imaging machine before and after the administration of the Gadovist® contrast agent (Germany).

When studying in T1-weighted mode, the following parameters were used: 384 × 387 matrix, TR (repetition time) - 560, TE (echo time) - 17, NEX (number of excitations) - 1, slice thickness - 4 mm, FOV (field of view) - 30 × 30.

For T2-weighted images: a matrix of 384 × 288, TR - 4000, TE - 95, NEX - 1, slice thickness - 4 mm, FOV - 30 × 30.

To obtain diffusion-weighted images, we used the following set of parameters for diffusion-weighted magnetic resonance images with an SE-echo-planar image (EPI): matrix 160 × 128, TR - 7500, TE - 83, NEX - 6, slice thickness - 4 mm, FOV - 30 × 30.

The following values of the diffusion factor (b) were used: b = 0, b = 500 and 1000 mm2 / s. The measured diffusion coefficient was calculated on the DWI with the largest diameter of meningiomas.

The values of the measured diffusion coefficient were calculated using the RadiAnt DICOM Viewer program.

Statistical data processing was performed using Microsoft Excel 2010 software. All measurements were checked for normality using a test Kolmogorov – Smirnov. The data obtained are evaluated using descriptive statistics methods. A comparative analysis of the measured diffusion coefficient values was performed using the Mann-Whitney U-test.

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Results and discussion

Published results of studies by several authors on the application of magnetic resonance imaging using diffusion-weighted images and calculating the measured diffusion coefficient in the differential diagnosis of brain meningiomas are interpreted ambiguously [12, 18, 22, 23]. In Sanverdi et al. [23] there are no significant differences between the measured diffusion coefficient of meningioi MI, MII and MIII types. But in a study by Hakyemez et al. [12] found that the average value of the measured diffusion coefficient of meningiomas MI is significantly higher than the measured diffusion coefficient of meningiomas MII / MIII (1170 and 750 mm^2/s, respectively). These data are confirmed by other authors.

The ambiguity of the results in these studies can be explained by different approaches to the method of calculating the measured diffusion coefficient according to diffusion-weighted images, as well as the lack of gradation in degrees of malignancy of meningomas in different countries as well as the sample size.

In general, the results obtained are consistent with the data from the world literature. Mean values of the measured diffusion coefficient of meningiomas MI and MIII, as well as MII and MIII have significant differences. It is believed that this relationship suggests that the calculation of the measured diffusion coefficient indirectly reflects pathological changes in the meningioma tissue.

The main issue of this study is to evaluate the effectiveness of magnetic resonance imaging using diffusion-weighted image programs and the calculation of the measured diffusion coefficient, in the differential diagnosis of the degree of malignancy of brain meningiomas.

Based on the available data, it can be assumed that the value of the measured diffusion coefficient of less than 750 mm^2/s makes it possible to distinguish between typical and atypical forms of meningiomas from anaplastic ones. Tang et al. As a threshold value of the measured diffusion coefficient for the differential diagnosis of meningiomas MI and MII, a value equal to 850 mm^2/s was obtained from MIII [27].

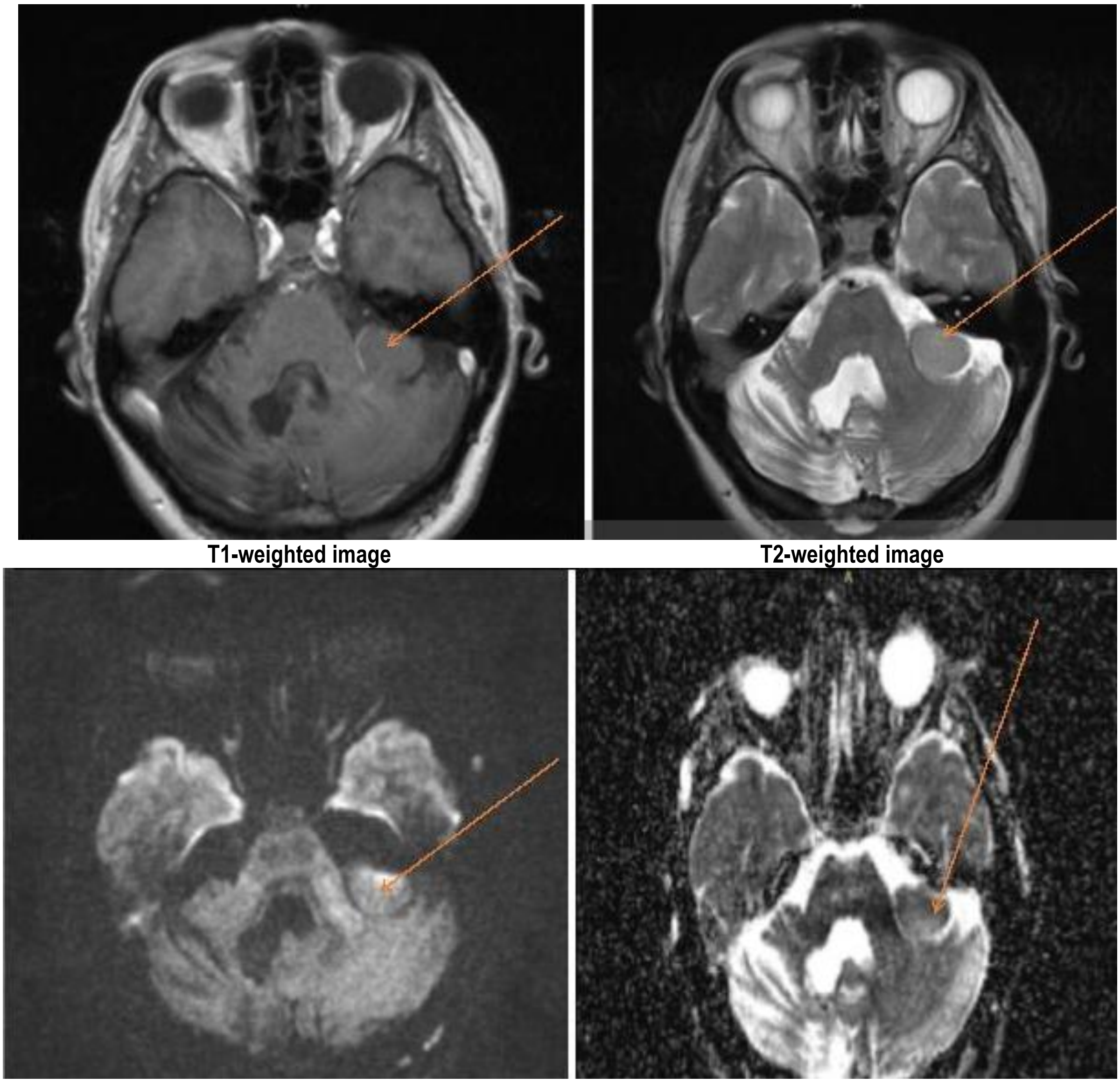
When analyzing the malignancy of meningiomas, meningiomas of I degree (typical, MI) prevailed - 31 cases (58.5%) and meningiomas of II degree of malignancy (atypical, MII) - 17 cases (32.1%), anaplastic MIII meningiomas were recorded in 5 cases (9.7%).

When analyzing the average values of the measured diffusion coefficient for all types of meningiomas, it was found that the average value of the measured diffusion coefficient:

for meningiomas, MI was 1399.5 ± 154.6 mm^2/s;

for meningiomas MII - 1136.2 ± 150 mm^2/s;

for meningiomas MIII - 706 ± 73.4 mm^2/s, respectively.



T1-weighted image T2-weighted image

DVI images Apparent diffusion coefficient

Figure 1. MR imaging of the temporal bone meningioma on the left.

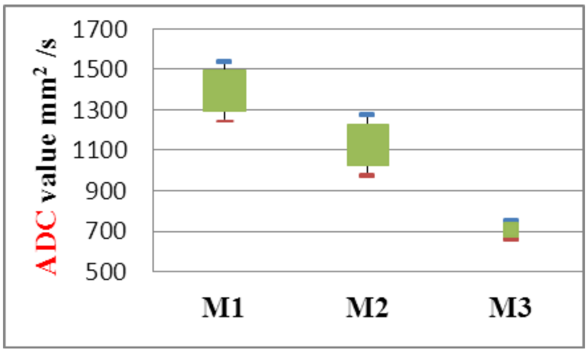


Figure 2. Comparison of average ADC values in meningiomas of various degrees of malignancy.

When comparing the average values of the measured diffusion coefficient, between meningiomas of varying degrees of malignancy, the following data were obtained.

No significant differences were found when comparing the measured diffusion coefficient of meningiomas M1 and M2 ($p = 0.723$).

But when comparing the measured diffusion coefficient of meningiomas M1 and M3, as well as M2 and M3, significant differences were found (M1/M3 - $p = 0.007$, M2 / M3 - $p = 0.0010$).

Of course, the presented study is not without flaws. So, the observation had only a retrospective character, a small number of patients and with a small number of anaplastic (MIII) forms of meningiomas were included in the complete sample in the East Kazakhstan region.

Our data, to some extent, are consistent with the results of studies conducted in 2012, found that the average value of the measured diffusion coefficient of meningiomas MI is significantly higher than the measured diffusion coefficient of meningiomas MII / MIII (1170 and 750 mm²/s, respectively) [12]. It is believed that this relationship suggests that the method of the measured diffusion coefficient indirectly reflects pathological changes in meningioma tissue [12].

To increase the reliability of the results obtained, research is needed on more cases of meningiomas using magnetic resonance imaging using diffusion-weighted images and calculating the measured diffusion coefficient with the complex characteristic values of the measured diffusion coefficient and the proliferative activity of the tumor.

Findings. The technique of magnetic resonance imaging using diffusion imaging programs and calculating the measured diffusion coefficient can be used as an additional non-invasive method for the differential diagnosis of intracranial meningiomas during magnetic resonance imaging.

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