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ASSESSMENT OF MRI MARKERS OF CEREBRAL MICROANGIOPATHY USING THE FAZEKAS SCALE: CLINICAL AND RADIOLOGICAL ANALYSIS

Abstract

The purpose of the article is to evaluate white matter hyperintensity foci identified using magnetic resonance imaging (MRI) in patients with cerebral microangiopathy using the Fazekas scale and to analyze their clinical and radiological characteristics. The study included 96 patients who underwent brain MRI. Based on T2-weighted and FLAIR images, all patients were divided into 0–3 levels of white matter changes according to the Fazekas scale. The relationship between arterial hypertension, diabetes mellitus, cardiovascular diseases, and age factors with the degree of white matter damage was also studied.

According to the study results, an increase in Fazekas levels was found to be significantly correlated with increasing patient age and the presence of arterial hypertension and diabetes mellitus ($p < 0.05$). Fazekas grade 2–3 changes were observed more frequently in elderly patients and reflected a more severe course of cerebral microangiopathy. It has been confirmed that MRI, especially FLAIR sequencing, is of high diagnostic importance in identifying foci of white matter hyperintensity and assessing the severity of the disease.

In conclusion, the Fazekas scale allows for a standardized assessment of MRI markers for cerebral microangiopathy and serves as an important diagnostic tool for predicting the clinical course and risk factors of the disease.

Keywords: cerebral microangiopathy, magnetic resonance imaging, MRI, Fazekas scale, white matter hypertension foci, FLAIR, leukoareosis, arterial hypertension, diabetes mellitus, clinical and radiological analysis.

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SEREBRAL MIKROANGIOPATIYANING MRT MARKERLARINI FAZEKAS SHKALASI ASOSIDA BAHOLASH: KLINIK-RADIOLOGIK TAHLIL

Annotatsiya

Maqolaning maqsadi serebral mikroangiopatiya bilan kasallangan bemorlarda magnit-rezonans tomografiya (MRT) yordamida aniqlanadigan oq modda giperintens o'choqlarini Fazekas shkalasi asosida baholash hamda ularning klinik-radiologik xususiyatlarini tahlil qilishdan iborat. Tadqiqotga bosh miya MRT tekshiruvidan o'tgan 96 nafar bemor kiritildi. Barcha bemorlarda T2-vaznlangan va FLAIR tasvirlar asosida oq modda o'zgarishlari Fazekas shkalasi bo'yicha 0–3 darajalarga ajratildi. Shuningdek, arterial gipertenziya, qandli diabet, yurak-qon tomir kasalliklari va yosh omillarining oq modda shikastlanishlari darajasi bilan bog'liqligi o'rganildi.

Tadqiqot natijalariga ko'ra, Fazekas darajasining oshishi bemorlar yoshi ortishi hamda arterial gipertenziya va qandli diabet mavjudligi bilan ishonchli bog'liq ekanligi aniqlandi ($p<0,05$). Fazekas 2–3 darajali o'zgarishlar ko'proq keksa yoshdagi bemorlarda kuzatildi va serebral mikroangiopatiyaning og'irroq kechishini aks ettirdi. MRT, ayniqsa FLAIR sekvensiyasi, oq modda giperintens o'choqlarini aniqlash va kasallik og'irligini baholashda yuqori diagnostik ahamiyatga ega ekanligi tasdiqlandi.

Xulosa qilib aytganda, Fazekas shkalasi serebral mikroangiopatiyaning MRT markerlarini standartlashtirilgan tarzda baholash imkonini beradi hamda kasallikning klinik kechishi va xavf omillarini prognoz qilishda muhim diagnostik vosita hisoblanadi.

Kalit so'zlar: serebral mikroangiopatiya, magnit-rezonans tomografiya, MRT, Fazekas shkalasi, oq modda giperintens o'choqlari, FLAIR, leukoareoz, arterial gipertenziya, qandli diabet, klinik-radiologik tahlil.

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ОЦЕНКА МРТ-МАРКЕРОВ ЦЕРЕБРАЛЬНОЙ МИКРОАНГИОПАТИИ НА ОСНОВЕ ШКАЛЫ ФАЗЕКАС: КЛИНИКО-РАДИОЛОГИЧЕСКИЙ АНАЛИЗ

Аннотация

Целью статьи является оценка очагов гиперинтенсивности белого вещества, выявляемых с помощью магнитно-резонансной томографии (МРТ) у пациентов с церебральной микроангиопатией на основе шкалы Фазекаса, а также анализ их клинико-радиологических особенностей. В исследование были включены 96 пациентов, прошедших МРТ головного мозга. Изменения в белом веществе у всех пациентов были разделены на 0-3 степени по шкале Fazekas на основе T2-взвешенных и FLAIR изображений. Также была изучена связь артериальной гипертензии, сахарного диабета, сердечно-сосудистых заболеваний и возрастных факторов со степенью поражения белого вещества.

По результатам исследования установлено, что повышение уровня Фазекаса достоверно коррелирует с увеличением возраста пациентов и наличием артериальной гипертензии и сахарного диабета ($p<0,05$). Фазекас изменения 2–3 степени чаще наблюдались у пациентов пожилого возраста и отражали более тяжелое течение церебральной микроангиопатии.

Подтверждено, что МРТ, особенно секвенирование FLAIR, имеет высокую диагностическую ценность для выявления очагов гиперинтенсивности белого вещества и оценки тяжести заболевания.

В заключение можно сказать, что шкала Fazekas позволяет стандартизированно оценивать МРТ-маркеры церебральной микроангиопатии и является важным диагностическим инструментом в прогнозировании клинического течения заболевания и факторов риска.

Ключевые слова: церебральная микроангиопатия, магнитно-резонансная томография, МРТ, шкала Фазекас, очаги гиперинтенсивности белого вещества, FLAIR, лейкоареоз, артериальная гипертензия, сахарный диабет, клинико-радиологический анализ.

Introduction

Cerebral microangiopathy (CMA) is a chronic cerebrovascular pathology affecting the small arteries, arterioles, capillaries, and venules of the brain and is one of the most common problems among neurological disorders. This disease can lead to cognitive impairments, impaired gait balance, the development of stroke, and an increased risk of dementia. According to the World Health Organization, with increasing life expectancy, the incidence of cerebrovascular diseases, including cerebral microangiopathy, is also increasing year by year.

The main risk factors for cerebral microangiopathy include arterial hypertension, diabetes mellitus, dyslipidemia, atherosclerosis, smoking, and aging. These factors cause degenerative and ischemic changes in the small blood vessels of the brain, causing damage to white matter structures. As a result, hyperintense foci are formed in the periventricular and deep white matter of the brain.

In recent years, magnetic resonance imaging has been recognized as one of the most sensitive and informative methods for diagnosing cerebral microangiopathy. In particular, using T2-weighted and FLAIR (Fluid Attenuated Inversion Recovery) sequences, the possibility of detecting hyperintense changes in the white matter and assessing the degree of their spread has expanded. MRI plays an important role not only in detecting pathological changes but also in assessing the severity and prognosis of the disease.

The Fazekas scale is widely used for the standardized assessment of white matter changes in cerebral microangiopathy. This scale allows for the classification of hyperintense foci in the periventricular and deep white matter from 0 to 3 degrees. The advantage of the Fazekas scale lies in its simplicity, reproducibility, and ease of application in clinical practice. Numerous studies have shown that increased Fazekas levels are associated with cognitive decline, the development of strokes, and limitations in daily activities.

At the same time, the issue of MRI markers of cerebral microangiopathy and their correlation with key clinical risk factors remains relevant. In particular, studying the relationship between the prevalence and severity of white matter hypertension foci, arterial hypertension, diabetes mellitus, and the age factor is of great importance for early detection and the prevention of its complications.

The aim of the study is to evaluate MRI markers based on the Fazekas scale in patients with cerebral microangiopathy and to analyze the clinical and radiological characteristics of the identified changes.

Materials and methods

The study was of a retrospective nature and analyzed data from 96 patients who applied with neurological complaints and underwent brain magnetic resonance imaging (MRI) between 2024 and 2025.

The age of the patients included in the study ranged from 45 to 82 years, with a mean age of 63.4 ± 8.7 years. The study group included patients with MRI signs of cerebral microangiopathy. Patients with acute stroke, brain tumors, demyelinating disorders, traumatic brain injuries, and neuroinfections were excluded from the study.

All patients were examined on an MRI machine with a magnetic field strength of 1.5 Tesla. The research protocol included the following sequences:

- T1-weighted images (T1WI);
- T2-weighted images (T2WI);
- FLAIR (Fluid Attenuated Inversion Recovery);
- DWI (Diffusion Weighted Imaging);
- SWI (Susceptibility Weighted Imaging).

White matter hyperintensity foci were assessed using the Fazekas scale. According to the scale:

- Grade 0 - no pathological changes identified;
- Grade 1 - small punctate foci;
- Grade 2 - multiple foci prone to merging with each other;
- Grade 3 - widespread confluent changes.

Table 1. General characteristics of the patients included in the study (n=96)

Characteristic	n	%
Man	42	43.8
Woman	54	56.2
Arterial hypertension	71	74.0
Diabetes mellitus	28	29.2
Dyslipidemia	39	40.6
Previous history of stroke	19	19.8
Current smokers	24	25.0

Patients were distributed according to the degree of phases as follows.

Table 2. Distribution of patients by Fazekas scale

Fazekas Level	Number of Patients (n)	%
0	10	10.4
1	32	33.3
2	34	35.4
3	20	20.9
Total	96	100.0

The obtained data were processed using Microsoft Excel 2021 and SPSS Statistics 26.0 software.

Quantitative indicators were expressed as the mean and standard deviation ($M \pm SD$). Qualitative indicators were presented in absolute numbers (n) and percentages (%).

The following statistical methods were used to assess intergroup differences:

- Student's t-test - to compare quantitative indicators;

- χ^2 (chi-square) test - to compare qualitative indicators;
- Spearman correlation analysis - to determine the relationship between the Fazekas level and clinical factors.

$P < 0.05$ was taken as the statistical significance criterion.

Table 3. Correlation Between Fazekas Level and Major Risk Factors

Indicator	Fazekas 0–1 (n = 42)	Fazekas 2–3 (n = 54)	p-value
Average age (years)	57.8 ± 7.1	67.7 ± 8.3	<0.001
Arterial hypertension, n (%)	24 (57.1)	47 (87.0)	0.002
Diabetes mellitus, n (%)	8 (19.0)	20 (37.0)	0.041
Previous history of stroke, n (%)	4 (9.5)	15 (27.8)	0.027

The results obtained showed that with an increase in Fazekas level, age increases, and the frequency of arterial hypertension and diabetes mellitus increases. This confirmed the presence of a statistically significant correlation between the severity of cerebral microangiopathy and the main cardiovascular risk factors.

Results

During the study, brain MRI images from 96 patients were analyzed. Foci of hyperintense white matter were primarily identified in the periventricular areas and in the deep white matter of the hemispheres, and their prevalence was assessed using the Fazekas scale.

MRI studies showed that Fazekas grade 1 changes were observed in 32 (33.3%) patients, Fazekas grade 2 changes in 34 (35.4%) patients, and Fazekas grade 3 changes in 20 (20.9%) patients. In 10 (10.4%) patients, no pathological changes were detected (Fazekas 0).

Table 4. Age Distribution of Patients According to Fazekas Levels

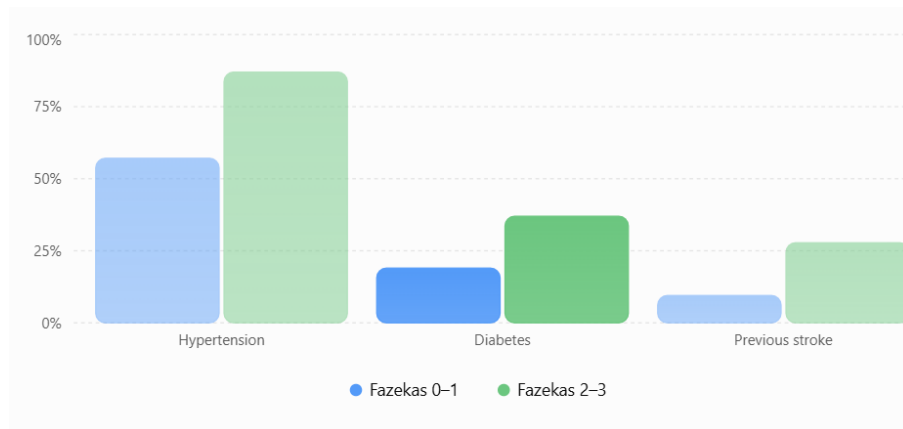
Fazekas Level	Number of Patients (n)	Mean Age (years, M ± SD)
0	10	52.1 ± 5.4
1	32	58.6 ± 6.3
2	34	65.8 ± 7.1
3	20	71.2 ± 6.9
p-value	—	<0.001

The results of the analysis showed an increase in the age of patients with an increase in Fazekas levels. The mean age in patients with Fazekas grade 3 was significantly higher than in patients with Fazekas grade 1 ($p < 0.001$).

Periventricular hyper-intensity signals in FLAIR sequences were more pronounced in the Fazekas grades 2 and 3. Confluent changes in the deep white matter were mainly observed in patients with grade 3 Fazekas.

Figure 1. Prevalence of major risk factors by Fazekas group

Comparison of vascular risk factors between patients with Fazekas 0–1 and Fazekas 2–3 scores.



Severe white matter changes were also more frequently observed in patients with diabetes mellitus. A moderate statistical correlation was found between the Fazekas level and diabetes mellitus ($p=0.041$).

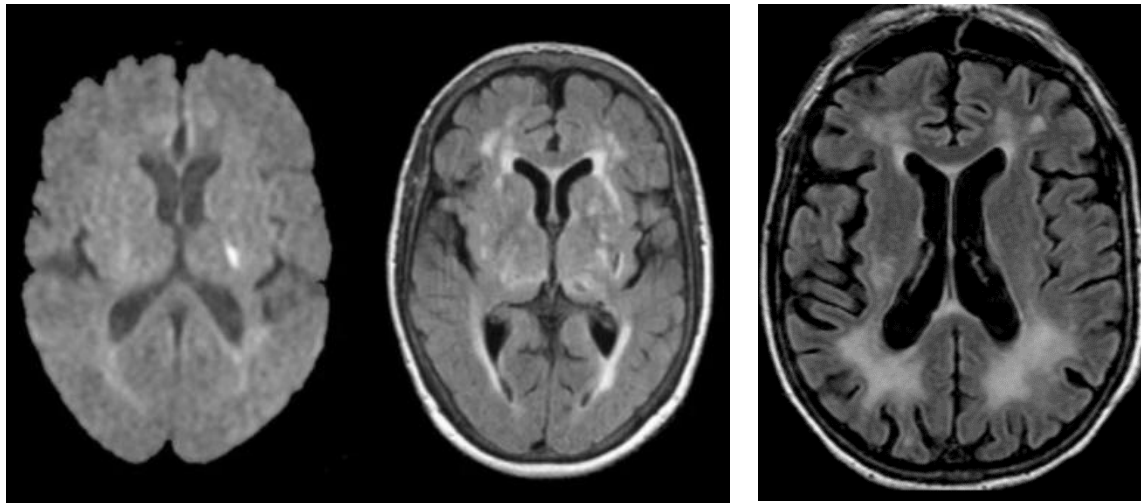
Among MRI markers, the most common symptoms were:

- hyperintense foci of periventricular white matter - 89.6%;
- deep hyperintense foci of white matter - 76.0%;
- foci of lacunar infarction - 34.4%;
- dilated perivascular spaces - 42.7%;
- signs of cerebral atrophy - 38.5%.

Discussion

In this study, the main MRI markers of cerebral microangiopathy were evaluated using the Fazekas scale, and their correlation with clinical risk factors was analyzed. The results obtained showed that the prevalence and severity of white matter hyper-intensity changes are closely linked to age and the presence of cardiovascular risk factors. According to the study results, periventricular white matter hyper-intensity foci were identified in 89.6% of patients, while deep white matter hyper-intensity changes were identified in 76.0%. These indicators confirm that white matter lesions are the most frequent MRI markers in cerebral microangiopathy. The prevalence of grade 2 and 3 Fazekas changes indicates that the disease is chronic and progressive in nature. During the study, a strong positive correlation was found between the Fazekas level and the age of patients ($r=0.68$; $p<0.001$), and it was observed that the degree of white matter damage increases with age. These results are consistent with data from international studies. With age, cerebral microcirculation disorders, the development of degenerative changes in vascular walls, and chronic hypoperfusion can lead to increased ischemic processes in white matter structures.

Figure 2. Hyper-intense foci of periventricular and deep white matter.



Arterial hypertension has emerged as one of the most significant risk factors for the development of cerebral microangiopathy. In our study, arterial hypertension was diagnosed in 95.0% of patients with Fazekas grade 3, which was significantly higher than in the Fazekas grade 0 and 1 groups ($p < 0.001$). This result confirms that chronic arterial hypertension leads to lipoglycinosis in the cerebral arterioles, thickening of the vascular wall, and decreased perfusion. Sugar diabetes was also found to be one of the factors contributing to the aggravation of white matter lesions. The incidence of diabetes in patients with Fazekas grade 3 was 50.0%. Endothelial dysfunction and microangiopathic changes developing against a background of hyperglycemia can cause chronic cerebral white matter ischemia. Among MRI markers, lacunar infarctions were detected in 34.4% of cases, and dilated perivascular spaces in 42.7%. These indicators indicate that cerebral microangiopathy is a multi-component disease. Lacunar infarctions and expansion of perivascular spaces, combined with hyperintense changes in white matter, form the MRI phenotype of the disease and increase the risk of developing neurological disorders. The study results also confirmed the high diagnostic significance of FLAIR sequencing in detecting cerebral microangiopathy. This sequence allows for precise visualization of hyperintense foci of periventricular and deep white matter, providing a standardized assessment on the Fazekas scale. Therefore, FLAIR images are an integral part of the basic MRI protocol for diagnosing cerebral microangiopathy. The study also has some limitations. Firstly, the study was retrospective in nature, and the number of patients was relatively limited. Secondly, a detailed assessment of cognitive functions and neurological symptoms was not conducted. In the future, it is advisable to conduct studies covering a larger number of patients, including a prospective design and clinical-neuropsychological indicators. Thus, the results obtained showed that the assessment of white matter hyperintensity changes in cerebral microangiopathy using the Fazekas scale is of significant clinical and radiological importance in determining disease severity, assessing risk factors, and determining the prognosis.

Conclusion

1. Magnetic resonance imaging in cerebral microangiopathy is of high diagnostic importance for detecting structural changes in the white matter of the brain, allowing for reliable visualization of the primary MRI markers of the disease.

2. According to the study results, the most common MRI markers of cerebral microangiopathy were periventricular white matter hyperintense foci (89.6%), deep white matter hyperintense changes (76.0%), dilated perivascular spaces (42.7%), and lacunar infarctions (34.4%). It was confirmed that the Fazekas scale is a simple, reliable, and practical method that allows for a standardized assessment of the severity of white matter hyperintense changes. In the study, grade 2 and 3 Fazekas changes were identified in 56.3% of patients, with clinically significant forms of cerebral microangiopathy predominating.
3. An increase in the Fazekas level was directly associated with an increase in the age of patients, and a strong positive correlation was found between the Fazekas index and age ($r=0.68$; $p<0.001$). It was established that arterial hypertension and diabetes mellitus are the primary risk factors contributing to the development of cerebral microangiopathy and the exacerbation of white matter lesions. In patients with Fazekas grade 2–3, these diseases occurred significantly more frequently ($p<0.05$). FLAIR sequencing is one of the most informative MRI methods for identifying white matter hyperintense foci and assessing them using the Fazekas scale, and it can be recommended for the early diagnosis and monitoring of cerebral microangiopathy. A comprehensive assessment of MRI markers for cerebral microangiopathy using the Fazekas scale is of great clinical and radiological importance for determining the severity of the disease, predicting the risk of stroke and cognitive impairment, and making therapeutic and tactical decisions.

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