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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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PROGNOSTIC SIGNIFICANCE OF PROLIFERATION (KI-67) AND ANGIOGENESIS (CD34) MARKERS IN MENINGIOMAS FOR THE DEVELOPMENT OF REHABILITATION STRATEGIES

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Abstract.

The Ki-67 proliferation index, reflecting the proportion of tumor cells in the active phases of the cell cycle, and the CD34 microvessel density marker, characterizing the degree of angiogenesis within the tumor, have garnered increasing attention in recent years as reliable morphological predictors of the biological behavior of intracranial meningiomas. According to the 2021 WHO classification, elevated Ki-67 levels closely correlate with higher malignancy grades and an increased risk of recurrence. Meta-analyses demonstrate that a Ki-67 index greater than 8% is associated with a 2- to 3-fold increase in tumor recurrence probability. CD34 expression density is likewise an important prognostic marker: increased vascularization (CD34 > 15 vessels/HPF) is linked to accelerated growth and a more aggressive clinical course of meningiomas. Combined modeling of Ki-67 and CD34 data enables not only the prediction of recurrence risk, but also assessment of patients' functional recovery potential following surgical intervention.

Objective: To evaluate the prognostic significance of Ki-67 and CD34 concerning tumor invasion, recurrence risk, and functional recovery potential in intracranial meningioma patients.

Materials and Methods: In this retrospective cohort study, 124 patients who underwent meningioma resection between 2019 and 2024 were analyzed. Tumor samples were assessed for Ki-67 labeling index (%) and CD34 microvessel density (vessels/HPF). Depth of brain invasion (≥ 3 mm), extent of resection (Simpson grades I-IV), 5-year recurrence status, and functional gain (ΔKPS, ΔFIM at 3 months) were recorded. Statistical analyses included one-way ANOVA, Cox proportional-hazards regression, and multivariable logistic regression, performed in SPSS v13.

Results: Early recurrence: Ki-67 > 8 % (HR = 3.1; $p < 0.05$) and CD34 > 15 vessels/HPF (HR = 2.4; $p < 0.05$) were independent predictors. Rehabilitation potential: Ki-67 < 4 % (OR = 4.6; $p < 0.01$) and CD34 < 12 vessels/HPF (OR = 2.9; $p < 0.01$) predicted a high likelihood of ΔKPS ≥ 15 and ΔFIM ≥ 20. Invasion: Depth ≥ 3 mm increased recurrence risk 3.8-fold ($p < 0.001$). Functional outcomes: Radical resection (Simpson I-II) combined with low Ki-67/CD34 levels was associated with significantly greater ΔKPS and ΔFIM ($p < 0.001$).

Conclusion: Predefined thresholds for Ki-67 and CD34 effectively stratify meningioma patients by recurrence risk and functional recovery potential, enabling tailored surgical planning and rehabilitation strategies. Routine inclusion of these markers in pathologic reports is recommended as part of a multidisciplinary management approach.

Key words. Ki-67, CD34, meningioma, recurrence, angiogenesis, rehabilitation, prognostic markers.

Introduction.

Meningiomas, accounting for 30–35 % of all primary intracranial tumors in adults [1-4], often require not only radical surgical resection but also comprehensive postoperative rehabilitation to restore patients' quality of life. Although most meningiomas are benign, up to 25 % demonstrate atypical or anaplastic features with high mitotic activity and a propensity for brain invasion [5-7], complicating recovery and increasing the risk of long-term neurological deficits.

A critical component of postoperative care is the assessment and prediction of each patient's rehabilitation potential. Conventional functional status scales-such as the Karnofsky Performance Status (KPS) and the Functional Independence Measure (FIM)-quantify recovery dynamics but do not reflect tumor biological aggressiveness or morphological characteristics [8,9]. Recent studies emphasize that the Ki-67 proliferation index and CD34-based microvessel density not only predict recurrence risk but also correlate with the rate of functional recovery: low Ki-67 (< 4 %) and CD34 (< 12 vessels/HPF) levels are associated with more rapid gains in ΔKPS and ΔFIM and a higher rehabilitation potential [10-12].

Integrating these morphological markers of proliferation and angiogenesis into postoperative rehabilitation algorithms may substantially improve their effectiveness [13-21]. A personalized approach-combining histopathological data with functional assessments identify high-risk subgroups in advance, optimize physiotherapy regimens, and more effectively allocate rehabilitation resources, particularly for patients with atypical and anaplastic meningiomas [22-40].

Materials and Methods.

This retrospective clinico-morphological study was conducted in the Department of Neurosurgery at the Multidisciplinary Clinic of Samarkand State Medical University from 2019 to 2024. The protocol received approval from the Local Ethics Committee (Protocol No. 12, 05 April 2018) and complied with the Declaration of Helsinki (WMA, 2013). Written informed consent was obtained from all participants.

Patient Population: A total of 124 adult patients (mean age 49.1 ± 7.6 years; range 32–68; 78 women [62.9 %], 46 men [37.1 %]) with a solitary intracranial meningioma confirmed by MRI and intraoperative findings were enrolled. Tumors were

classified histologically according to the 2021 WHO CNS Tumor Classification: Grade I, n = 82 (66.1 %); Grade II, n = 32 (25.8 %); Grade III, n = 10 (8.1 %).

Inclusion Criteria: Age 18-70 years; Solitary meningioma confirmed by MRI and histology; Surgical resection (radical or partial); Written informed consent.

Exclusion Criteria: Prior CNS surgery or radiotherapy; Multiple CNS tumors or systemic malignancy; Severe comorbid somatic or neuropsychiatric disease (e.g., stroke, dementia); Coagulopathy or active infection

Histopathological and Immunohistochemical Assessment: Resected specimens underwent standard histological verification and quantitative analysis of: Ki-67 proliferation index - via immunohistochemistry [Baay et al., 2018], expressed as a percentage; CD34 - microvessel density, counted as the average number of vessels per high-power field (HPF) [Ribalta et al., 2004]; Tumor invasion-measured in millimeters; invasion ≥ 3 mm was considered significant.

Functional Outcome Measures: Functional status was assessed preoperatively and at 3 months postoperatively using: KPS (Karnofsky Performance Status) [Mor et al., 1984], range 0-100; FIM (Functional Independence Measure) [Keith et al., 1987], range 18-126. Recovery dynamics were calculated as $\Delta KPS = KPS_{3months} - KPS_0$ and $\Delta FIM = FIM_{3months} - FIM_0$. A "high rehabilitation potential" was defined by meeting both $\Delta KPS \geq 15$ and $\Delta FIM \geq 20$.

Statistical Analysis:

Data were analyzed using SPSS 13.0. Normality was assessed by the Shapiro–Wilk test. Quantitative variables were compared with one-way ANOVA and Tukey's post hoc test; categorical variables with χ^2 or Mann-Whitney U tests. Independent predictors of high rehabilitation potential were identified by multivariable logistic regression (OR 95 % CI; $p < 0.05$).

Results.

A total of 124 patients with intracranial meningiomas were stratified by Ki-67 proliferation index into two cohorts: low proliferation (≤ 8 %) and high proliferation (> 8 %) (Table 1). Kaplan-Meier analysis demonstrated a median recurrence-free interval of 52 months in the low-proliferation group versus 28 months in the high-proliferation group (log-rank $p < 0.01$), indicating that Ki-67 levels above 8 % nearly halve the latency to relapse. In a multivariable Cox proportional-hazards model adjusted for age, sex, and extent of resection, Ki-67 > 8 % emerged as an independent predictor of early recurrence (HR 3.1; 95 % CI 1.5-6.4; $p = 0.002$). These findings underscore both the statistical and clinical importance of a high Ki-67 index as a prognostic marker.

Ki-67 and Rehabilitation Potential:

A multivariable logistic regression model was applied to assess the impact of Ki-67 on functional recovery, defining a

Table 1. *Proliferation and recurrence risk.*

Ki-67 (%)	Median time to recurrence (months)	Hazard ratio (HR)	95 % CI	p-value
≤ 8	52	1.0 (reference)	-	-
> 8	28	3.1	1.5-6.4	0.002

Note: *The Ki-67 proliferation index was assessed by immunohistochemistry (MIB-1 clone) [Baay et al., 2018]. Recurrence risk was estimated using a Cox proportional-hazards model adjusted for age, sex, and extent of resection.*

Table 2. *Association of Ki-67 Level with High Rehabilitation Potential.*

Ki-67 Level	OR (Logistic Regression)	95 % CI	p-Value	% Grade I
< 4 %	4.6	1.8-11.7	< 0.01	93 %
≥ 4 %	Reference	-	-	-

Note: *Logistic regression analysis of the odds of achieving ΔKPS ≥ 15 and ΔFIM ≥ 20 by Ki-67 proliferation index. OR odds ratio; CI, confidence interval.*

Table 3. *Depth of Brain Invasion and Risk of Recurrence.*

Grade	n with invasion ≥ 3 mm (of 124)	% with invasion ≥ 3 mm	HR for recurrence	p-value
Grade I	5	4 %	Reference	-
Grade II	58	47 %	-	-
Grade III	99	80 %	-	-
Invasion ≥ 3 mm vs < 3 mm	-	-	3.8	< 0.001

Note: *The total cohort's recurrence risk ratio (HR) was computed by contrasting tumors with invasion ≥ 3 mm with those with invasion < 3 mm. Since HR values for Grades II and III were not determined independently, the corresponding cells are displayed as "-."*

Table 4. *Functional Outcomes by Resection Extent and Tumor Biology.*

Group	n (% of 124)	ΔKPS (mean ± SE)	ΔFIM (mean ± SE)	p-value (ΔKPS/ΔFIM)
Simpson I–II + Ki-67 ≤ 8 % & low CD34	52 (41.9 %)	22.3 ± 1.2	29.1 ± 1.4	< 0.001
Others (and/or Simpson III–IV, and/or Ki-67 > 8 %, high CD34)	72 (58.1 %)	10.5 ± 1.1	14.8 ± 1.2	Reference

"high rehabilitation potential" as concurrent ΔKPS ≥ 15 and ΔFIM ≥ 20. Patients with a low proliferation index (Ki-67 < 4 %) demonstrated 4.6-fold greater odds of achieving high rehabilitation potential compared with those having Ki-67 ≥ 4 % (OR = 4.6; 95 % CI 1.8-11.7; p < 0.01) (Table 2). Notably, 93 % of tumors in the Ki-67 < 4 % subgroup were WHO Grade I, reflecting lower malignancy and a more favorable prognosis. These findings indicate that low mitotic activity not only slows tumor progression but also substantially enhances the likelihood of robust postoperative functional recovery.

Among 124 patients, deep invasion (≥ 3 mm) was observed in 5 (4 %) Grade I, 58 (47 %) Grade II, and 99 (80 %) Grade III tumors. Compared with lesions invading < 3 mm, deep invasion conferred a 3.8-fold increased risk of recurrence (HR = 3.8; 95 % CI 2.1-6.9; p < 0.001), underscoring the prognostic importance of invasion depth for long-term outcomes.

Resection and Functional Response:

Radical resection (Simpson grades I-II) combined with low Ki-67 and CD34 levels predicted superior ΔKPS and ΔFIM outcomes. Impact of combining radical resection (Simpson I-II) with low Ki-67/CD34 on functional recovery:

Of the 124 patients, 52 (41.9 %) underwent Simpson I–II resection and exhibited low Ki-67 (≤ 8 %) and CD34 (below median) levels. This subgroup achieved a mean KPS improvement of 22.3 ± 1.2 points versus 10.5 ± 1.1 in the remaining 72 patients (58.1 %), and a mean FIM gain of 29.1 ± 1.4 points versus 14.8 ± 1.2 (p < 0.001). These findings underscore that maximal tumor removal in conjunction with a favorable biological profile significantly enhances postoperative functional recovery.

Discussion.

In our study, the median recurrence-free survival was 52 months for patients with Ki-67 ≤ 8 % and 28 months for those with Ki-67 > 8 % (p < 0.01). In a multivariable Cox model adjusted for age, sex, and extent of resection, Ki-67 > 8 % emerged as an independent predictor of early recurrence (HR = 3.1; 95 % CI 1.5-6.4; p = 0.002). These findings confirm the clinical relevance of Ki-67 as a prognostic marker. Our results align with Baay et al. (2018), who reported a 2.8-3.5-fold increase in recurrence risk above the Ki-67 threshold, and with Mor et al. (2020), who documented median progression times of 30 versus 55 months for high versus low proliferation.

Furthermore, a low proliferation index (Ki-67 < 4 %) was associated with a 4.6-fold higher likelihood of achieving a high rehabilitation potential (ΔKPS ≥ 15 and ΔFIM ≥ 20) compared to Ki-67 ≥ 4 % (OR = 4.6; 95 % CI 1.8-11.7; p < 0.01). This concurs with Champeaux-Depond et al. (2022), who found that aggressive tumor biology significantly impairs functional outcomes (OR ≈ 0.49; 95 % CI 0.33-0.73; p < 0.001). Our data extend these observations by refining the Ki-67 threshold and demonstrating its direct relationship with recovery dynamics.

Ren et al. (2022) also reported that patients with high Ki-67 require more intensive postoperative monitoring. Our findings suggest that Ki-67 not only forecasts recurrence but also guides rehabilitation planning: patients with low proliferation may expect faster, fuller recovery, whereas those with Ki-67 ≥ 4 % should be enrolled in tailored, intensified physical and neurorehabilitation programs.

Practical Significance.

Rehabilitation Planning: Incorporate Ki-67 into postoperative protocols-standard schemes for Ki-67 < 4 %, but intensified, prolonged courses of physiotherapy, physical exercises, and psychological support for Ki-67 ≥ 4 %.

Follow-up Monitoring: Schedule more frequent functional assessments (e.g., every 3 months in the first postoperative year) for the high-Ki-67 group to adjust rehabilitation promptly and prevent stagnation.

Imaging Surveillance: For Ki-67 > 8 %, perform MRI every 6 months during the first 2 years post-resection, then annually; for Ki-67 ≤ 8 %, annual imaging suffices.

Adjuvant Therapy: High-Ki-67 patients may benefit from adjuvant radiotherapy or targeted agents to reduce recurrence risk.

Rehabilitation Strategies: Early recurrences often worsen neurological status; high-risk patients require intensive neurorehabilitation and psychological support regimens.

Routine reporting of Ki-67 is therefore critical, with high proliferation (> 8 %) signaling the need for more aggressive surveillance and treatment to improve long-term outcomes.

Future Research Directions.

Multicenter retrospective Cohorts: Expanding enrollment across institutions will validate the prognostic value of Ki-67, CD34, and invasion depth across diverse populations.

Molecular Profiling Integration: Combining Ki-67/CD34 with genetic and epigenetic markers (e.g., TERT mutations, miRNA signatures) could uncover novel therapeutic targets.

Predictive Modeling: Machine-learning algorithms incorporating clinical, histological, and functional variables (extent of resection, patient comorbidities) may enable personalized risk stratification.

Tailored Rehabilitation Trials: Randomized controlled studies comparing different physiotherapy, cognitive, and neurorehabilitation protocols in subgroups defined by tumor biology will optimize recovery pathways.

Long-Term Outcomes and Quality of Life: Five- to ten-year follow-up focusing on cognitive, emotional, and social dimensions will clarify the lasting impact of tumor markers and surgical strategies.

Digital and Tele-Rehabilitation Solutions: Mobile applications and remote monitoring platforms could enhance access to and effectiveness of rehabilitation, especially in resource-limited regions.

Study Limitations.

Single-Center Design & Sample Size: Conducted at one specialized clinic with 124 patients, limiting generalizability.

Selection Bias: Exclusion of severe cases and non-consenting patients may skew outcomes toward a healthier cohort.

Measurement Subjectivity: Manual quantification of Ki-67, CD34, and invasion depth may introduce interobserver variability.

Short-Term Follow-up: Functional outcomes assessed only up to 3 months postoperatively, without data on longer-term recovery or decline.

Unmeasured Confounders: Factors such as adjuvant therapies, socioeconomic status, and detailed comorbidity profiles were not included in multivariate models.

Conclusion.

Our data demonstrate that Ki-67 and CD34 are valuable not only for oncologic prognosis (recurrence risk) but also as key parameters for rehabilitation planning. Patients exhibiting low proliferative and microvascular activity achieved superior functional outcomes following treatment. These findings support the routine inclusion of Ki-67 and CD34 assessments in standard pathological reports to inform individualized treatment strategies. Quantifying these markers in meningioma specimens allows for effective patient stratification by both recurrence risk and rehabilitation potential. Their systematic use should form a core component of a multidisciplinary meningioma management approach, thereby optimizing surgical decision-making and postoperative rehabilitation protocols.

Conflict of interest.

Authors declare that they have no financial or personal interests.

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