

MOTOR FUNCTIONAL RECOVERY AFTER REHABILITATION FOLLOWING PARASAGITTAL MENINGIOMA SURGERY: A PROSPECTIVE INTERVENTIONAL STUDY FROM VIETNAM

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This prospective single-group interventional study aimed to evaluate motor functional recovery and identify factors associated with rehabilitation outcomes in patients following parasagittal meningioma surgery. Thirty patients presenting with postoperative motor weakness after tumor resection participated in a standardized 2-week inpatient rehabilitation program combining physical and occupational therapy, followed by outpatient continuation. Motor and functional outcomes were assessed using the Motor Assessment Scale (MAS), Manual Muscle Testing (MMT), and Functional Independence Measure (FIM) at baseline, 1 month, and 3 months post-intervention. Significant improvements were observed across all scales, with MAS increasing from 30.1 ± 10.9 to 37.8 ± 8.5 and 39.2 ± 8.4 , MMT from 126.3 ± 19.8 to 136.0 ± 20.2 and 141.6 ± 18.8 , and FIM from 85.0 ± 29.6 to 93.4 ± 20.3 and 99.7 ± 18.6 ($p < 0.05$ for all comparisons). Generalized Estimating Equations analysis revealed that age, peritumoral edema and preoperative motor weakness were not significant predictors. These findings support the role of early, targeted rehabilitation as a beneficial component of postoperative care for patients with parasagittal meningioma. Larger controlled studies with longer follow-up are required to better delineate recovery trajectories and clarify factors influencing rehabilitation outcomes in this population.

Keywords: Parasagittal meningioma, motor function recovery, postoperative rehabilitation, functional outcomes, brain tumor surgery.

I. INTRODUCTION

Meningioma (MN) is the most common benign primary intracranial tumor, with a cumulative incidence rate of 7.8 per 100,000 person-years.¹ The term parasagittal meningioma (PSM) refers to meningiomas involving the superior sagittal sinus, the adjacent convexity dura mater, and the neighboring falx cerebri. Along with convexity meningiomas, PSMs represent one of the most frequent anatomical subtypes, accounting for approximately 18-30% of all

cases.² Clinically, meningiomas are typically slow-growing tumors, and their manifestations are diverse and variable depending on tumor location.³ Parasagittal meningiomas may involve the cerebral motor cortex and exert compressive effects on this functional region, leading to common symptoms such as headache, seizures, and motor weakness.²

Advances in anesthesiology, neuroimaging, and particularly in surgical techniques—such as microsurgery, radiosurgery, and neuronavigation—have enabled more accurate diagnosis and radical resection of meningiomas, thereby reducing the risks of intraoperative bleeding and neurological injury.⁴ However,

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despite these improvements, recent studies still report postoperative complication rates of 45-50% in parasagittal meningioma, reflecting the complexity of the lesion and the functional eloquence of the surrounding brain tissue.⁵⁻⁸ In parasagittal meningiomas, motor deficits are of particular concern due to their high prevalence. This suggests that the demand for postoperative rehabilitation (rehabilitation medicine) among these patients may be substantial yet insufficiently addressed. To the best of our knowledge, no study has specifically evaluated the outcomes of motor rehabilitation in patients following surgical removal of parasagittal meningiomas. Our primary hypothesis was that early postoperative rehabilitation would lead to significant improvement in motor function, as reflected by increases in MAS, MMT, and FIM scores compared with pre-intervention levels. Therefore, we conducted this study with the primary objective of assessing motor functional recovery after meningioma surgery and analyzing factors associated with motor rehabilitation outcomes in this patient population.

II. PARTICIPANTS AND METHODS

1. Inclusion and exclusion criteria

Patients aged 18 years or older were eligible for inclusion if they had a confirmed diagnosis of parasagittal meningioma and presented with postoperative motor weakness. In addition, participants were required to be able to cooperate in motor function assessments and to have provided written informed consent after receiving a full explanation of the study's objectives, procedures, and interventions.

Exclusion criteria included a history of stroke or other central nervous system disorders unrelated to meningioma; significant impairment of consciousness or severe

cognitive dysfunction, defined as a Mini-Mental State Examination (MMSE) score \leq 20; presence of progressive or life-threatening medical comorbidities such as severe infection, anemia, coagulopathy, hepatic failure, renal failure, heart failure, acute myocardial infarction, pneumonia, or respiratory failure requiring invasive ventilation; and current pregnancy at the time of enrollment.

2. Study design

This single-group interventional study, comparing outcomes before and after a structured rehabilitation program, was conducted at the Department of Rehabilitation Medicine and the Center for Neurosurgery, Viet Duc University Hospital, Hanoi, Vietnam, from May 2024 to April 2025.

Sample size

The sample size was calculated based on an expected mean improvement of 10 points in the Motor Assessment Scale (MAS), with a standard deviation of 20 points. Assuming a Type I error (α) of 0.05 and a Type II error (β) of 0.2 (corresponding to a statistical power of 80%), the minimum required sample size was determined to be 30 patients.

Study protocol

Patients diagnosed with parasagittal meningioma after surgical resection were screened for study eligibility based on predefined inclusion and exclusion criteria. Individuals meeting all criteria were thoroughly informed about the study's objectives and procedures. Individuals who voluntarily agreed to participate were provided written informed consent prior to enrollment.

At baseline (enrollment), the following data were collected: (1) demographic information; (2) comorbid medical conditions; (3) preoperative and postoperative MRI characteristics of the

tumor; and (4) surgical details. Each patient subsequently underwent a neurological and rehabilitation assessment focusing primarily on motor function, including evaluation of muscle strength, mobility, and functional performance relevant to postoperative motor recovery.

During postoperative care, patients participated in a standardized 2-week inpatient rehabilitation program, consisting of 2-hour daily sessions, 5 days per week, integrating physical therapy and occupational therapy. After discharge, they were encouraged to continue outpatient rehabilitation at local facilities. The rehabilitation program was structured using the International Classification of Functioning, Disability and Health (ICF) as a guiding framework for assessment and goal setting, rather than as a requirement to intervene in all domains during each session. The daily therapy primarily focused on motor recovery, including muscle strengthening, balance training, mobility exercises, and task-oriented functional practice. The ICF components addressed were limited mainly to body function and activity domains relevant to postoperative motor deficits, while participation and environmental factors were supported through counseling, caregiver education, and home-exercise planning. The intervention process involved an initial assessment, individualized goal setting, selection of motor-focused therapeutic exercises, periodic evaluation, and adjustment based on clinical progress. Techniques such as PNF and Bobath-based facilitation were applied selectively depending on each patient's neurological status. The acute phase emphasized preventing complications and maintaining basic mobility; the inpatient phase focused on motor strengthening, balance improvement, and functional independence in daily activities; and the post-discharge phase encouraged continued mobility and activity practice at home and local

facilities. Although the overall structure of the program was standardized, specific exercises were individualized to match each patient's functional status.

Following discharge, patients continued to receive routine follow-up at the Departments of Rehabilitation and Neurosurgery, Viet Duc University Hospital. Follow-up assessments were scheduled at 1 month and 3 months post-discharge, during which functional recovery outcomes were re-evaluated.

Study outcomes

The Motor Assessment Scale (MAS) is a standardized tool widely used in clinical studies on stroke and other motor disorders to evaluate functional motor performance. It comprises eight items, including five related to mobility and three related to upper-limb function. Each item is scored from 0 to 6, yielding a total score ranging from 0 to 48 points, with higher scores indicating better motor function.

The Manual Muscle Testing (MMT) scale is a clinical method for assessing muscle strength through manual resistance. In this study, MMT was performed on 16 muscle groups bilaterally (32 muscle groups in total), including shoulder flexion-extension-abduction-adduction, elbow flexion-extension, wrist flexion-extension, hip flexion-extension-abduction-adduction, knee flexion-extension, and ankle flexion-extension. Each muscle or muscle group was graded on a 0-5 scale, and the total MMT score represented the sum of strength scores across all muscle groups, yielding a maximum possible score of 160.

The Functional Independence Measure (FIM) is an 18-item scale used to assess the level of functional independence in patients. It includes 13 items related to motor and self-care activities and 5 items assessing cognitive and communication functions. Higher FIM

scores reflect greater functional autonomy and independence in daily activities.

Statistical analysis

Descriptive statistics were used to summarize clinical, radiological, and surgical characteristics of the study population ($n = 30$). Continuous variables were presented as mean \pm standard deviation (SD), minimum, and maximum values, while categorical variables were expressed as frequencies and percentages.

Changes in functional outcomes-including Motor Assessment Scale (MAS), Manual Muscle Testing (MMT), and Functional Independence Measure (FIM) scores-were analyzed at three time points: baseline (pre-rehabilitation), 1 month, and 3 months after intervention. For normally distributed continuous variables, differences across time points were assessed using the paired Student's t-test, whereas non-normally distributed variables were analyzed using the Wilcoxon signed-rank test. Data visualization was performed using spaghetti plots to depict longitudinal trends in MAS, MMT, and FIM scores over time, showing mean values with standard deviation error bars. Corresponding bar plots illustrated the magnitude of improvement at each follow-up compared with baseline, together with p-values indicating the level of statistical significance.

To identify independent predictors associated with improvement in MAS, MMT, and FIM scores over time, a generalized estimating equations

(GEE) model with repeated measures was fitted, incorporating follow-up assessments at 1 and 3 months. The model adjusted for age, presence of peritumoral edema and preoperative motor weakness.

All analyses were conducted using R language version 4.3.2, with statistical significance set at a threshold of $p < 0.05$.

3. Ethical considerations

The study protocol was reviewed and approved by the Master's Program Entrance Proposal Review Board of Hanoi Medical University (Approval No. 452/QĐ-ĐHYHN, dated February 20th, 2025). All participants provided written informed consent after being fully informed about the objectives, content, and procedures of the study. Personal information was kept strictly confidential, and all research activities complied with Vietnamese regulations on biomedical research ethics and the ethical principles of the Declaration of Helsinki.

III. RESULTS

A total of 30 patients were included in the study, with a mean age of 58 years and a predominance of females. Most patients presented with hemispheric motor deficits before surgery. All patients exhibited postoperative motor weakness. Hemiparesis was the predominant pattern (93.3%), while 6.7% presented with bilateral lower-limb weakness (Table 1).

Table 1. Clinical characteristics (n = 30)

Characteristics	Results
Female sex, n (%)	19 (63%)
Age (years), mean \pm SD	58 \pm 10

Characteristics	Results
Preoperative clinical symptoms, n (%)	
Headache	14 (47%)
Nausea/Vomiting	2 (6.7%)
Blurred vision	5 (17%)
Hemiparesis	21 (70%)
Sensory disturbance	13 (43%)
Cerebellar signs	1 (3.3%)
Seizures	8 (27%)
Cranial nerve palsy	2 (6.7%)
Proptosis	1 (3.3%)
Endocrine dysfunction	1 (3.3%)
Psychiatric symptoms	2 (6.7%)
Coma	1 (3.3%)
Time from first symptom to surgery (months), mean \pm SD	2.39 \pm 2.56
Postoperative motor weakness, n (%)	
Hemiparesis	28 (93.3%)
Bilateral lower-limb weakness	2 (6.7%)

The majority of tumors were single lesions and located in the anterior or posterior one-third of the superior sagittal sinus. Typical meningioma features-including homogeneous enhancement, peritumoral edema, midline shift, and dural attachment-were frequently observed. Regarding operative and postoperative

characteristics, most patients underwent complete or near-complete tumor resection, with a low rate of postoperative complications. Atypical meningiomas were the most frequent histopathological subtype. Postoperative MRI confirmed gross total resection in the vast majority of cases. (Table 2)

Table 2. Magnetic resonance imaging and surgical characteristics (n = 30)

Characteristics	Results
MAGNETIC RESONANCE IMAGING	
Number of tumors, n (%)	
Single tumor	29 (97%)
Multiple tumors	1 (3.3%)
Tumor location, n (%)	
Anterior one-third	16 (53%)
Middle one-third	2 (6.7%)
Posterior one-third	12 (40%)
Maximum tumor diameter (mm), mean \pm SD	43 \pm 15
Tumor characteristics, n (%)	
Homogeneous	19 (63%)
Cystic	0 (0%)
Hemorrhagic	4 (13%)
Calcified	1 (3.3%)
Adjacent bone changes, n (%)	
No change	17 (57%)
Thickened or hyperostotic bone	5 (17%)
Eroded or destructed bone	8 (27%)
Peritumoral brain edema, n (%)	21 (70%)
Midline shift, n (%)	
None	16 (53%)
Grade I (5 mm)	8 (27%)
Grade II (5-10 mm)	3 (10%)
Grade III (>10 mm)	3 (10%)
Extra-axial signs, n (%)	
Broad dural attachment	22 (73%)
Well-defined margins	30 (100%)
Cortical gyral compression	21 (70%)
Dural tail sign	20 (67%)

Characteristics	Results
Invasive features, n (%)	
Vascular invasion	3 (10%)
Venous sinus invasion	12 (40%)
Cranial nerve invasion	0 (0%)
Bone or soft tissue invasion	6 (20%)
SURGICAL CHARACTERISTICS	
Operative time (minutes), mean ± SD	138 ± 58
Postoperative complications, n (%)	
Cerebral edema	3 (10%)
Intracerebral hemorrhage	4 (13%)
Histopathological subtype, n (%)	
Meningothelial	6 (20%)
Transitional	2 (6.7%)
Fibrous	8 (27%)
Angiomatous	1 (3.3%)
Atypical	13 (43%)
Postoperative MRI findings, n (%)	
No residual tumor	29 (97%)
Residual tumor present	1 (3.3%)

All three scales-MAS, MMT, and FIM-showed significant improvement following rehabilitation. The MAS score increased from 30.1 ± 10.9 pre-intervention to 37.8 ± 8.5 at 1 month and 39.2 ± 8.4 at 3 months (p < 0.001 at both time points). The MMT score improved from 126.3 ± 19.8 to

136.0 ± 20.2 at 1 month and 141.6 ± 18.8 at 3 months (p < 0.001). Similarly, the FIM score rose from 85.0 ± 29.6 to 93.4 ± 20.3 at 1 month (p = 0.006) and 99.7 ± 18.6 at 3 months (p < 0.001). (Figure 1-3)

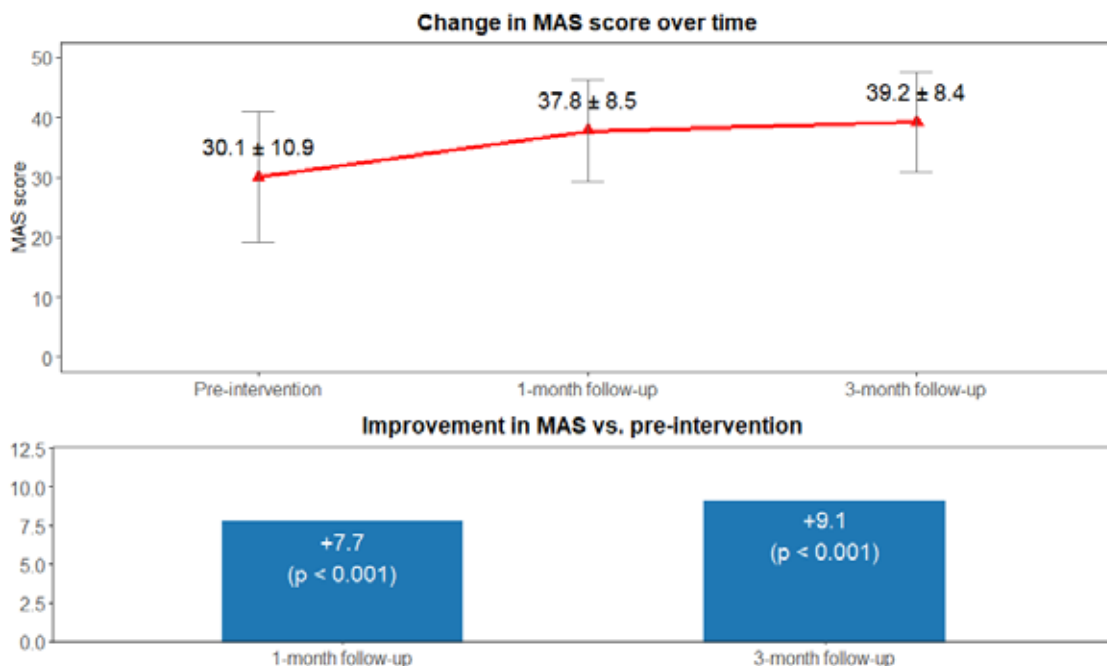


Figure 1. Improvement in MAS score over time (n = 30)

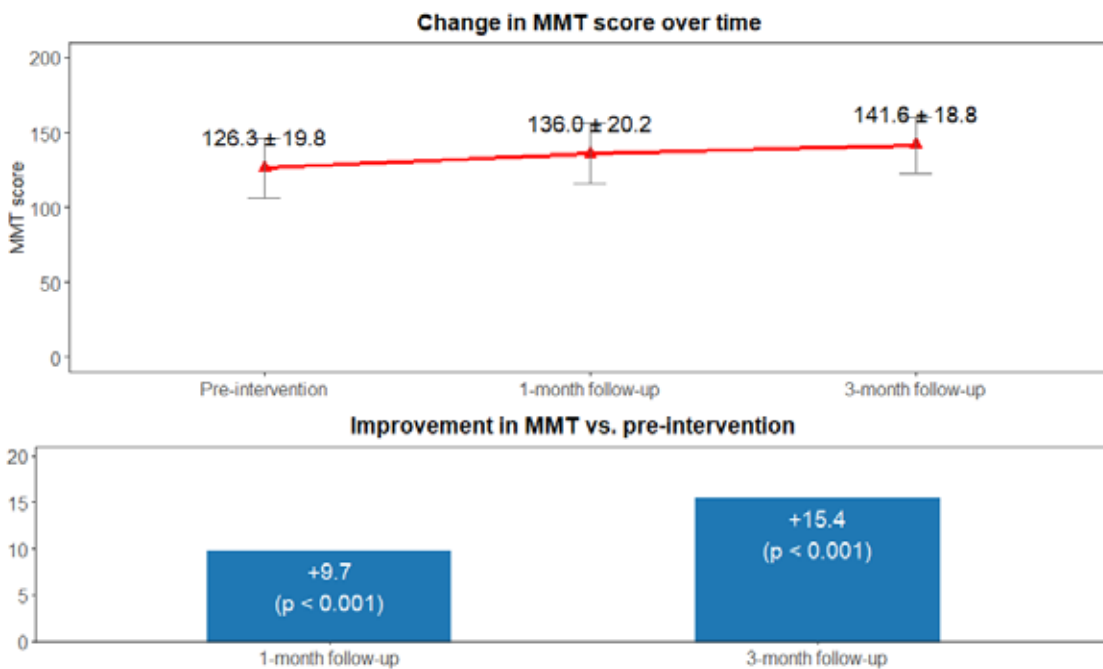


Figure 2. Improvement in MMT over time (n = 30)

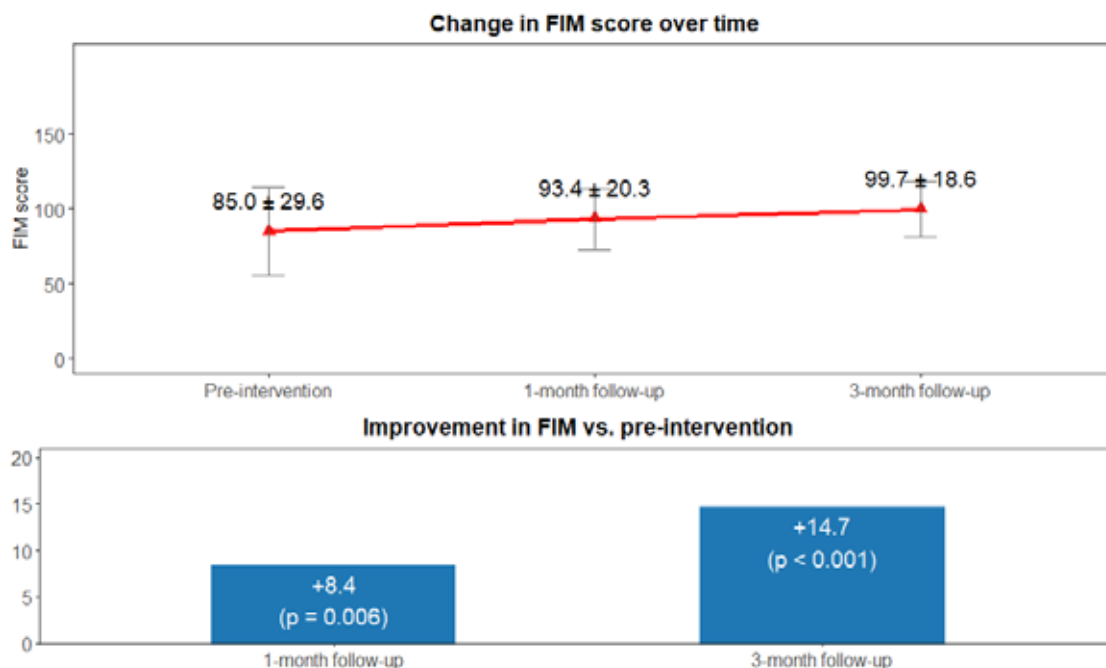


Figure 3. Improvement in FIM over time (n = 30)

Across all three functional scales (MAS, MMT, and FIM), significant improvements were observed at both 1 and 3 months post-rehabilitation compared with baseline (all p <

0.001). Age, presence of peritumoral edema and preoperative motor weakness were not significantly associated with functional outcomes.

Table 3. Generalized Estimating Equations model of factors associated with motor functional improvement in patients after parasagittal meningioma surgery

Factor	MAS		MMT		FIM	
	β	95% CI	β	95% CI	β	95% CI
Intercept	25.8	6.4 - 45.2	121.9	84.2 - 159.5	74.6	22.4 - 126.8
Age (years)	-0.0	-0.3 - 0.2	-0.0	-0.6 - 0.5	-0.1	-0.7 - 0.6
Preoperative motor weakness (present vs. absent)	4.9	-2.4 - 12.2	4.8	-11.6 - 21.1	14.1	-3.4 - 31.6
Presence of peritumoral edema (vs. none)	3.3	-3.6 - 10.2	3.8	-12.2 - 19.8	6.5	-14.2 - 27.1
At 1 month vs. pre-rehab	7.7	6.2 - 9.3	9.7	8.1 - 11.3	8.4	3.0 - 13.9
At 3 months vs. pre-rehab	9.1	7.3 - 11.0	15.4	13.8 - 17.0	14.7	8.8 - 20.6

IV. DISCUSSION

Our study demonstrates that motor and functional recovery after parasagittal meningioma surgery follows a clear improving trajectory, with MAS increasing by +7.7 and +9.1, MMT by +9.7 and +15.4, and FIM by +8.4 and +14.7 at 1 and 3 months, respectively. Although these gains are clinically meaningful, they are modest compared with several published rehabilitation cohorts. Huang et al. reported substantial FIM improvements in patients with primary brain tumors undergoing inpatient rehabilitation ($F = 46.84$, $p < 0.05$).⁹ Greenberg et al. observed a mean +17.9-point increase in FIM after 24 days of inpatient rehabilitation in a large mixed brain tumor sample,¹⁰ between January 1993 and August 2004. Particular attention was paid to age and sex distribution, onset-to-admission interval, length of stay, functional status at admission and discharge, functional gain (DeltaFI change and Geler-Kulcu et al. reported MAS and FIM motor gains of approximately +10-15 points over a single hospitalization period in meningioma and glioma patients.¹¹ Similarly, Fu et al. described even larger FIM increases (+21.7 points) in high-grade glioma after intensive inpatient therapy,¹² whereas Bartolo et al. also found greater functional gains among meningioma patients compared with stroke and glioblastoma groups following a structured 4-week rehabilitation program.¹³ In contrast, the improvements observed in our study were lesser.

Several factors may explain this difference. First, our sample size was relatively small, which increases the uncertainty of the estimated functional improvements and may reduce the precision of the effect estimates. Second, our intervention period was relatively short (2-week inpatient program), whereas many prior studies implemented 3-4 weeks of intensive inpatient therapy or prolonged outpatient

programs. Third, the functional baseline of our cohort was relatively high-meningioma patients generally present with less severe neurological impairment than patients with infiltrative gliomas or large postoperative deficits—thereby reducing the “room for improvement.” Finally, the heterogeneity of outpatient rehabilitation after discharge, which we could not fully monitor, may have contributed to more conservative functional gains by 3 months. Nevertheless, despite these differences in magnitude, the direction and pattern of recovery in our cohort are consistent with the broader neuro-oncology rehabilitation literature: early postoperative rehabilitation is associated with steady improvements in strength, motor control, and functional independence across the first months of recovery.

The mechanisms underlying this improvement likely involve combined neurobiological and functional processes. Surgical decompression relieves pressure on cortical and subcortical structures, facilitating recovery of neural conduction, while structured rehabilitation enhances neuroplasticity, cortical reorganization, and sensorimotor integration. Concurrently, targeted physical and occupational therapy helps maintain muscle strength, restore coordination, and prevent complications of prolonged immobility. The cumulative effect of multimodal, continuous, and individualized rehabilitation enables patients to regain independence in key daily activities.¹⁴ Accordingly, rehabilitation should be recognized as a core component of postoperative care, rather than a supplementary measure. Early and sustained intervention not only optimizes neurological recovery but also improves quality of life, reduces care dependency, and supports community reintegration, particularly in patients with favorable prognoses such as those with parasagittal meningioma.

In our study, age, peritumoral edema, and preoperative motor weakness were not significantly associated with postoperative functional recovery. Although older age is commonly associated with slower neurological restitution,¹⁵ we did not observe a measurable age effect in this cohort. Likewise, peritumoral edema-often considered a surrogate for cortical irritation, mass effect, or greater surgical complexity¹⁶-did not demonstrate a significant relationship with functional outcomes. Preoperative motor weakness, which intuitively might limit recovery potential,¹⁷ also showed no significant association. These negative findings should be interpreted cautiously. The relatively small sample size increases the uncertainty of the estimated effects, while the short follow-up interval may not fully capture the trajectory of neurological recovery. Moreover, outpatient rehabilitation after discharge was heterogeneous and not fully controllable, introducing additional variability. Taken together, the absence of statistically significant associations in this study likely reflects methodological constraints rather than definitive evidence that these clinical factors lack prognostic value. Larger studies with longer follow-up are needed to clarify their true impact.

This study has several important limitations. First, the overall sample size was small, which not only increases the uncertainty of the estimated functional improvements but also markedly limits the ability to detect associations with clinical covariates. When the total cohort is small, any subgroup or covariate-based analysis becomes even more underpowered, which likely contributed to the absence of significant findings for factors such as age, peritumoral edema, and preoperative motor weakness. Second, the follow-up duration was short, capturing only early postoperative recovery and potentially missing later functional trajectories. Third, the

study did not include a control group, preventing separation of the effects of rehabilitation from natural postoperative neurological recovery. Finally, although the inpatient program was standardized, outpatient rehabilitation after discharge varied considerably between patients and could not be controlled, introducing a potential confounding influence on 3-month outcomes. These limitations indicate that the results should be interpreted with caution, and larger, controlled studies with longer follow-up are needed to confirm these findings.

V. CONCLUSION

In this prospective interventional study of patients with postoperative motor weakness following parasagittal meningioma surgery, significant improvements in motor performance and functional independence were observed over the first three months of recovery. Gains in MAS, MMT, and FIM scores suggest a consistent pattern of early functional restoration associated with structured postoperative rehabilitation. Although no clinical variable-including age, peritumoral edema, or preoperative motor weakness-was identified as significant predictors of outcome, the small sample size and methodological constraints limit definitive conclusions regarding prognostic factors. These findings support the role of early, targeted rehabilitation as a beneficial component of postoperative care for patients with parasagittal meningioma. Larger controlled studies with longer follow-up are required to better delineate recovery trajectories and clarify factors influencing rehabilitation outcomes in this population.

DECLARATIONS

Conflicting interests

The authors declare no competing interests in preparing this article.

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Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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