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Subtypes and influencing factors of postoperative burden outcomes in patients with moyamoya disease: A latent transition analysis based on multidimensional evaluation

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Title: Subtypes and influencing factors of postoperative burden outcomes in patients with moyamoya disease: A latent transition analysis based on multidimensional evaluation

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Abstract

Background: Moyamoya disease is a chronic, progressive cerebrovascular condition, and revascularisation surgery remains its primary treatment. However, how patients' burden evolves throughout the perioperative period remains understudied. We classified patients' self-perceived burden into subtypes before and after revascularisation, tracking how individuals shifted between subtypes. Factors linked to an unfavourable burden outcome were examined. The findings may inform perioperative risk stratification and the timing of assessment.

Methods: This longitudinal study followed adults scheduled for elective cerebral revascularisation at a tertiary Chinese hospital from July 2025 to June 2026. Each patient completed assessments one day before surgery (T1) and one day before discharge (T2). Burden was measured with the Self-Perceived Burden Scale, and anxiety was measured with the Generalized Anxiety Disorder-7. The LPA used the three SPBS subscale scores (physical, emotional and financial burden), and GAD-7 entered the model as an auxiliary variable. Latent transition analysis modelled how individual patients shifted between subtypes. Remaining in a higher-burden subtype or progressing into a subtype defined an unfavourable outcome. Univariate comparisons screened for candidate factors, which were subsequently subjected to multivariable logistic regression.

Results: The sample comprised 171 patients (male: 54.4%), with a mean age of 44.7 years. Three burden subtypes (low, moderate and high) were identified at both assessments; between assessments, the low-burden subtype prevalence decreased from 36.3% to 13.5%, and the high-burden subtype increased from 14.6% to 27.5%, leaving 133 patients (77.8%)

with an unfavourable outcome. Postoperative aphasia was associated with higher odds of an unfavourable outcome (OR: 5.387, 95% CI: 1.200–24.189, P = 0.028), whereas a history of anxiety or depression was associated with lower odds (OR: 0.360, 95% CI: 0.158–0.820, P = 0.015).

Conclusions: In this cohort of 171 adults undergoing elective revascularisation for moyamoya disease, 77.8% demonstrated no change to a lighter profile. Postoperative aphasia indicated the highest risk, whereas a history of anxiety or depression was linked to better outcomes, suggesting that preadmission burden and anxiety screening, closer monitoring for aphasia and predischarge reassessment may inform perioperative patient management.

Keywords: Moyamoya disease; Self-perceived burden; Burden outcome; Latent profile analysis; Latent transition analysis

Background

Moyamoya disease (MMD) is a chronic, progressive cerebrovascular disease characterised by the formation of abnormal smoke-like vascular networks at the base of the skull [1]. Its incidence exhibits marked regional variation, with a higher incidence in East Asian populations than in Western populations, together with familial aggregation and genetic susceptibility [2]. Studies in China have reported a crude incidence of 0.59 and prevalence of 1.01 per 100,000 in 2016, with a clear predominance in the middle-aged group (mean: 44.45 years) [3]. Currently, extracranial–intracranial revascularisation is the main approach for improving cerebral perfusion and reducing stroke recurrence risk; this disease mainly presents as ischaemic and haemorrhagic stroke [4] and may also manifest as transient

ischaemic attack (TIA), epilepsy, headache, and cognitive impairment. Recurrent strokes can lead to severe neurological impairment [5] and impose multiple physical, psychological, financial, and social burdens on patients.

Burden is central to psychosocial research involving patients with chronic or serious illness, encompassing disease, treatment, financial and caregiving dimensions [6]. Most studies in chronic populations are cross-sectional; thus, how perceived burden changes over time has drawn little attention [7]. Perceived burden is a measurable physical and psychosocial indicator and, once each patient's burden profile and its postoperative change have been characterised, a potentially modifiable one. We therefore followed moyamoya patients across the perioperative period to assess multidimensional burden. LPA identified pre- and postoperative burden classes, and LTA tracked how patients moved between them. Our aim was to help the perioperative team identify the patients most in need of intervention.

Methods

Study participants

Inpatients scheduled for elective cerebral revascularisation who were admitted to the Department of Neurosurgery of a general hospital from 1 July 2025 to 30 June 2026 were selected; those meeting the following inclusion criteria of the cohort were enrolled: (1) met the diagnostic criteria for MMD [8], diagnosed via digital subtraction angiography (DSA) and underwent cerebral revascularisation; (2) aged ≥ 18 years; (3) were aware of their own condition; (4) were conscious, free of cognitive impairment or mental disorders, and able to communicate normally; and (5) provided informed consent, voluntarily participated in this study, and signed the consent form. The exclusion criteria were: (1) severe cognitive or

mental disorders and (2) other severe systemic diseases, such as malignant tumours or major organ failure. This study was approved by the Ethics Committee of Huashan Hospital, Fudan University (Approval No. KY2025-912).

Research instruments

General information questionnaire

The questionnaire collected two types of information. The demographic aspect encompassed sex, age, marital status, income level, family history, and disease duration; the disease-related portion encompassed diagnosis, surgical site, procedure type, preoperative mRS score [9], intraoperative blood loss, pre-and postoperative stroke, epilepsy, limb dysfunction, sleep disorders, dysphagia, and postoperative aphasia.

Modified Rankin Scale (mRS)

Preoperative disability was rated with the modified Rankin Scale (mRS), a published scale that was not developed for this study [9]. Outside stroke, the mRS has become a routine measure of outcome in critically ill neurological patients, in neurosurgical cohorts, and after endovascular treatment[10].We used a Chinese translated version. The scale runs from 0 (no symptoms) to 6 (death). The responsible physician recorded the score at baseline. We collected the preoperative value only, as the study focused on perioperative burden rather than postoperative functional outcome.

Self-perceived burden scale (SPBS)

The SPBS was used to measure self-perceived burden [11]. It contains 10 items encompassing physical, emotional and financial burden, with each item scored from 1 (never)

to 5 (always); total scores range from 10 to 50, with higher scores indicating greater burden. The 10 items cover three domains: physical burden (items 1 and 2), emotional burden (items 3 and 4), and financial burden (items 5 to 10), which yielded the three domain scores entered into the latent profile analysis. Item 8 is worded in the opposite direction and was reverse-scored before aggregation. In the present sample, Cronbach's alpha was 0.94 (T1) and 0.95 (T2) for the total SPBS score.

Generalized anxiety disorder-7 (GAD-7)

Current anxiety symptoms were assessed with the GAD-7 [12],We adopted it for the neuropsychological component of postoperative burden, as has been done in other disease states [13].Each item is scored 0–3 for a total score of 0–21; scores of 5, 10 and 15 indicate mild, moderate and severe anxiety, respectively. The Chinese version has demonstrated good reliability and validity [14].In the present sample, Cronbach's alpha was 0.94 at both T1 and T2 for the GAD-7.

Mutuality scale (MS)

The MS assesses the quality of the patient–caregiver relationship [15]. It comprises 15 items across four dimensions: love, shared pleasurable activities, shared values and reciprocity. Each item is rated from 0 (not at all) to 4 (a great deal), giving a total score of 0 to 60, with higher scores indicating better relationship quality. We used the Chinese version introduced by Liu [16]. The scale was measured at T1 only and was not repeated at T2, as it was intended to characterise the preoperative patient–caregiver relationship, whereas the T2

assessment focused on patient-reported burden and anxiety. In the present sample, Cronbach's alpha was 0.96 (T1) for the MS total score.

Data collection and quality control

Data were collected at two time points: one day before surgery (T1) and one day before discharge (T2). Two trained nurses administered the questionnaires in a face-to-face manner at both time points; disease-related items were completed by the responsible physicians. Patients were informed of the purpose of the study and provided written informed consent; they were also assured that the responses were anonymous. When patients posed questions, the nurses answered with the same wording, and any unclear information was immediately explained. Questionnaires were collected only after being checked for completeness.

Statistical methods

All analyses were performed in SPSS 27.0 and Mplus 8.3. Continuous variables are summarised as means ± SDs or medians (interquartile ranges), and categorical variables are summarised as counts (%). An unfavourable outcome was defined as the absence of improvement in latent profile membership from T1 to T2, specifically including patients remaining in a higher-burden profile or transitioning into this profile. A favourable outcome was defined as maintaining the low-burden profile or transitioning to a lower-burden profile. For between-group comparisons, we used chi-square tests for categorical variables and Mann-Whitney U tests for continuous variables. When expected frequencies were less than 5, the Fisher's exact test was applied to 2 × 2 tables, and exact P values for larger tables were

estimated via Monte Carlo simulation with 20,000 replicates. Variables that reached $P < 0.05$ in the univariate analysis, together with family history of MMD given its clinical relevance, were entered into a multivariable logistic regression model. Results are reported as regression coefficients and odds ratios (ORs) with 95% confidence intervals (CIs). Model calibration was assessed using the Hosmer-Lemeshow test. Two-sided $P < 0.05$ was considered to indicate statistical significance.

Latent profile analysis (LPA) classified patients by maximum-likelihood estimation, with the number of classes determined via the BIC, aBIC, AIC, bootstrap likelihood ratio test (BLRT), and Lo–Mendell–Rubin test (LMR). The LPA was based on three continuous SPBS subscale scores (physical, emotional and financial burden),and the GAD-7 total score was included as an auxiliary variable to describe each latent class. Classification was judged acceptable when the mean posterior probability exceeded 0.7 and the entropy was ≥ 0.8. Latent transition analysis (LTA) then modelled movement between profiles from T1 to T2. Profile structure was comparable across the two occasions: the same three-class solution was supported at both time points, and the classes kept the same ordering and clinical interpretation. Each patient's T1 and T2 classes were combined into a transition pattern.

Results

Participant characteristics

We screened 181 patients for eligibility and included 171 in the analysis (94.5% of those screened). Of the 10 excluded patients, 4 did not undergo the planned surgery and 6 withdrew after severe postoperative complications; none was excluded for incomplete questionnaires. All 171 completed both assessments, one day before surgery (T1) and one

day before discharge (T2) (Fig. 1).The sample comprised 93 men (54.39%) and 78 women (45.61%). The mean age was 44.70 ± 9.78 years. Sixty-six patients (38.6%) had a college education or above, 110 (64.33%) were employed, and 159 (92.98%) were married. Twenty-four patients (14.04%) had a family history of MMD, 75 (43.86%) had a history of hypertension, and 39 (22.81%) had a history of anxiety and depression.

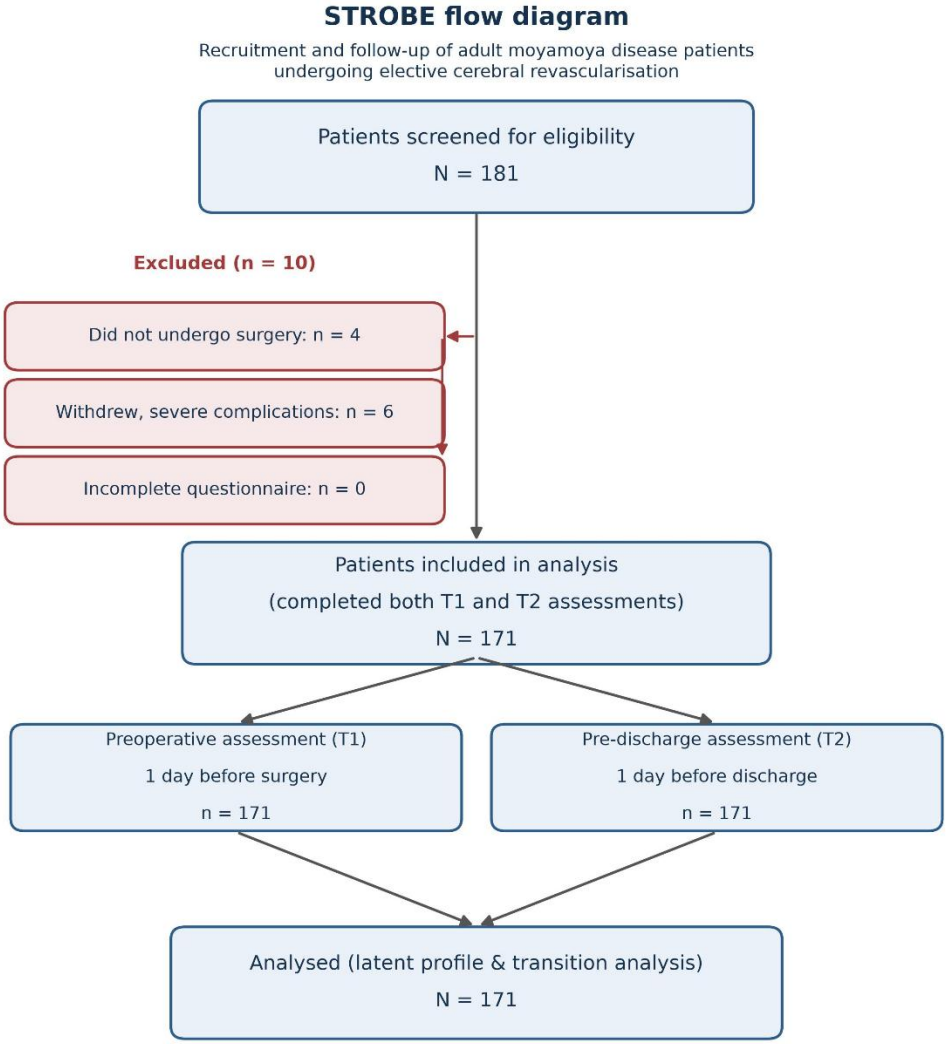


Figure 1. Flow of participants through the study

The descriptive statistics are summarised in Table 1. Mean SPBS total scores were 22.3 ± 8.7 at T1 and 22.8 ± 7.4 at T2. Emotional burden was the dominant dimension at both assessments (13.3 ± 5.5 and 13.5 ± 4.7), whereas physical and financial scores remained low (ranging from 4.2 to 4.7). Anxiety slightly increased from 6.1 ± 5.0 to 7.2 ± 4.5. Mild symptoms represented the most common category at T2 (74 patients, 43.3%), and 49 patients (28.7%) scored 10 or above (an increase from 25.1% at T1).

Table 1. Descriptive statistics of self-perceived burden, three-dimensional scores and anxiety at T1 and T2 (N = 171)

Variable	T1 Mean ± SD; Median (IQR)	T2 Mean ± SD; Median (IQR)
GAD-7	6.1 ± 5.0; 6.0 (2.0–9.5)	7.2 ± 4.5; 7.0 (4.0–10.0)
SPBS	22.3 ± 8.7; 22 (1 6.0, 28.0)	22.8 ± 7.4; 21 (19.0, 28.0)
Physical burden	4.2 ± 1.8; 4.0 (3.0–5.0)	4.5 ± 1.5; 4.0 (4.0–6.0)
Financial burden	4.7 ± 2.0; 5.0 (3.0–6.0)	4.7 ± 1.7; 4.0 (4.0–6.0)
Emotional burden	13.3 ± 5.5; 13.0 (9.0–17.0)	13.5 ± 4.7; 12.0 (11.0–17.0)

Note: Cronbach's alpha for internal consistency was 0.94 (T1) and 0.95 (T2) for the SPBS, 0.94 at both time points for the GAD-7, and 0.96 (T1) for the Mutuality Scale; T2 Mutuality Scale data were not collected.

LPA of preoperative and postoperative burden in patients with MMD

We retained the three-class solution at both time points. At T1, the entropy was 0.881, and LMR and BLRT tests were both significant ($P < 0.01$); at T2, the entropy was 0.911 (LMR $P = 0.003$; BLRT $P < 0.01$). The five-class T1 solution also passed the LMR test ($P =$

0.049); however, its smallest class comprised only 1.2% of the sample, which was insufficient to form a stable profile. The T2 four-class solution (LMR P = 0.031) yielded slightly lower AIC and BIC values, but the additional class largely split from an existing class with limited clinical interpretability; we therefore retained the more parsimonious three-class solution. The same class count at T1 and T2 was needed for the transition analysis. Average posterior probabilities for all classes exceeded 95% (Table 2, Fig. 2).

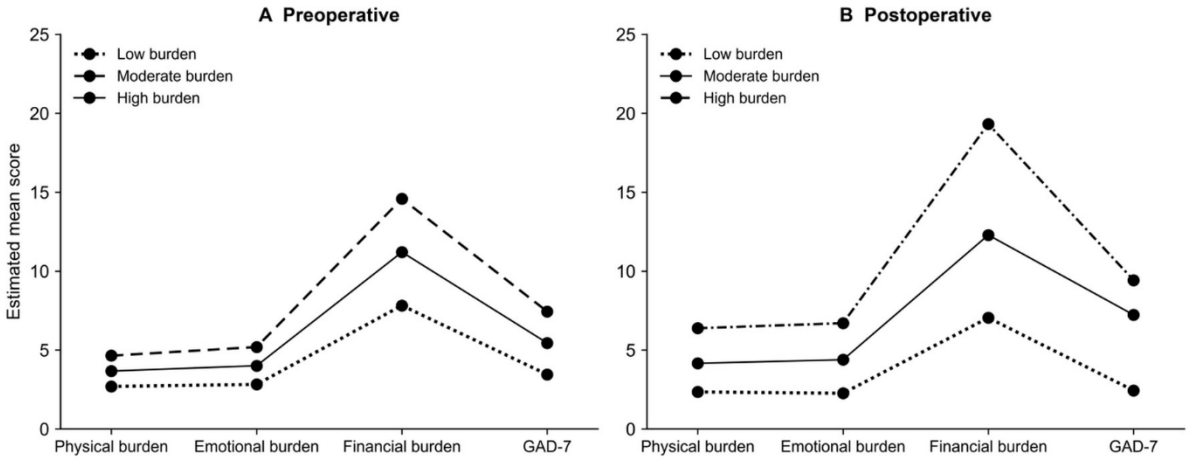


Figure 2. Latent profile analysis model plots of preoperative and postoperative burden in patients with MMD

Table 2. Model fit indices for latent profile analysis of preoperative and postoperative burden in patients with MMD (N = 171)

Time point	Model	No. of free parameters	AIC	BIC	aBIC	Entropy	*P* (LMR)	*P* (BLRT)	Class proportions
T1	1	6	2490.808	2509.658	2490.659	–	–	–	–
	2	10	2303.485	2334.901	2303.237	0.811	0.006	0.007	0.667/0.333
	3	14	2208.5	2252.5	2208.1	0.881	<	0.001	0.363/0.491/0

			22	06	76		0.001		.146
	4	18	2173.573	2230.123	2173.127	0.849	0.178	< 0.001	0.269/0.251/0.404/0.076
	5	22	2158.808	2227.925	2158.264	0.888	0.049	< 0.001	0.269/0.409/0.012/0.064/0.246
T2	1	6	2308.024	2326.874	2307.875	–	–	–	–
	2	10	2068.737	2100.154	2068.490	0.891	< 0.001	< 0.001	0.667/0.333
	3	14	1967.289	2011.272	1966.942	0.911	0.003	< 0.001	0.134/0.591/0.275
	4	18	1886.624	1943.174	1886.178	0.923	0.031	< 0.001	0.474/0.146/0.269/0.111
	5	22	1875.466	1944.583	1874.922	0.887	0.476	< 0.001	0.129/0.485/0.123/0.163/0.100

A latent transition analysis of pre- and postoperative burden in patients with MMD

Transition patterns were heterogeneous across baseline classes. Among patients in the T1 low-burden class (n = 62), only 16 (25.8%) retained their class; 30 (48.4%) progressed to the moderate-burden class, and 16 (25.8%) progressed to the high-burden class. Among patients in the T1 moderate-burden class (n = 84), 56 (66.7%) remained stable, 22 (26.2%) progressed to the high-burden class, and 6 (7.1%) improved to the low-burden class. Among patients in the T1 high-burden class (n = 25), 16 (64.0%) transitioned downwards (15 to the moderate-burden class and 1 to the low-burden class) and 9 (36.0%) remained in the high-burden class (Table 3).

Table 3. Latent class transition matrix from T1 to T2 in patients with MMD (N = 171)

T1 class, n (%)	C1 (low)	C2 (moderate)	C3 (high)	Total

C1 (low), n = 62	16 (25.8)	30 (48.4)	16 (25.8)	62 (100.0)
C2 (moderate), n = 84	6 (7.1)	56 (66.7)	22 (26.2)	84 (100.0)
C3 (high), n = 25	1 (4.0)	15 (60.0)	9 (36.0)	25 (100.0)
Total	23 (13.5)	101 (59.1)	47 (27.5)	171 (100.0)

Note. C1 = low burden class; C2 = moderate-burden class; C3 = high burden class.

Among the 171 patients, 81 (47.4%) retained their T1 class membership, whereas 90 (52.6%) changed classes at T2. Overall, 68 patients (39.8%) transitioned to a higher-burden class, and 22 (12.9%) transitioned to a lower-burden class (Table 4).

Table 4. Summary of latent class transition directions in patients with MMD (N = 171)

Transition pattern	n	%
Retained class membership	81	47.4
Upgraded to a higher-burden class	68	39.8
Downgraded to a lower-burden class	22	12.9
Total	171	100.0

Between T1 and T2 the class distribution moved towards higher burden: the proportion in the low-burden class fell from 36.3% (n = 62) to 13.5% (n = 23), while that in the high-burden class nearly doubled, from 14.6% (n = 25) to 27.5% (n = 47). The moderate-burden class remained the largest throughout (49.1% at T1, n = 84; 59.1% at T2, n = 101) (Fig. 3).

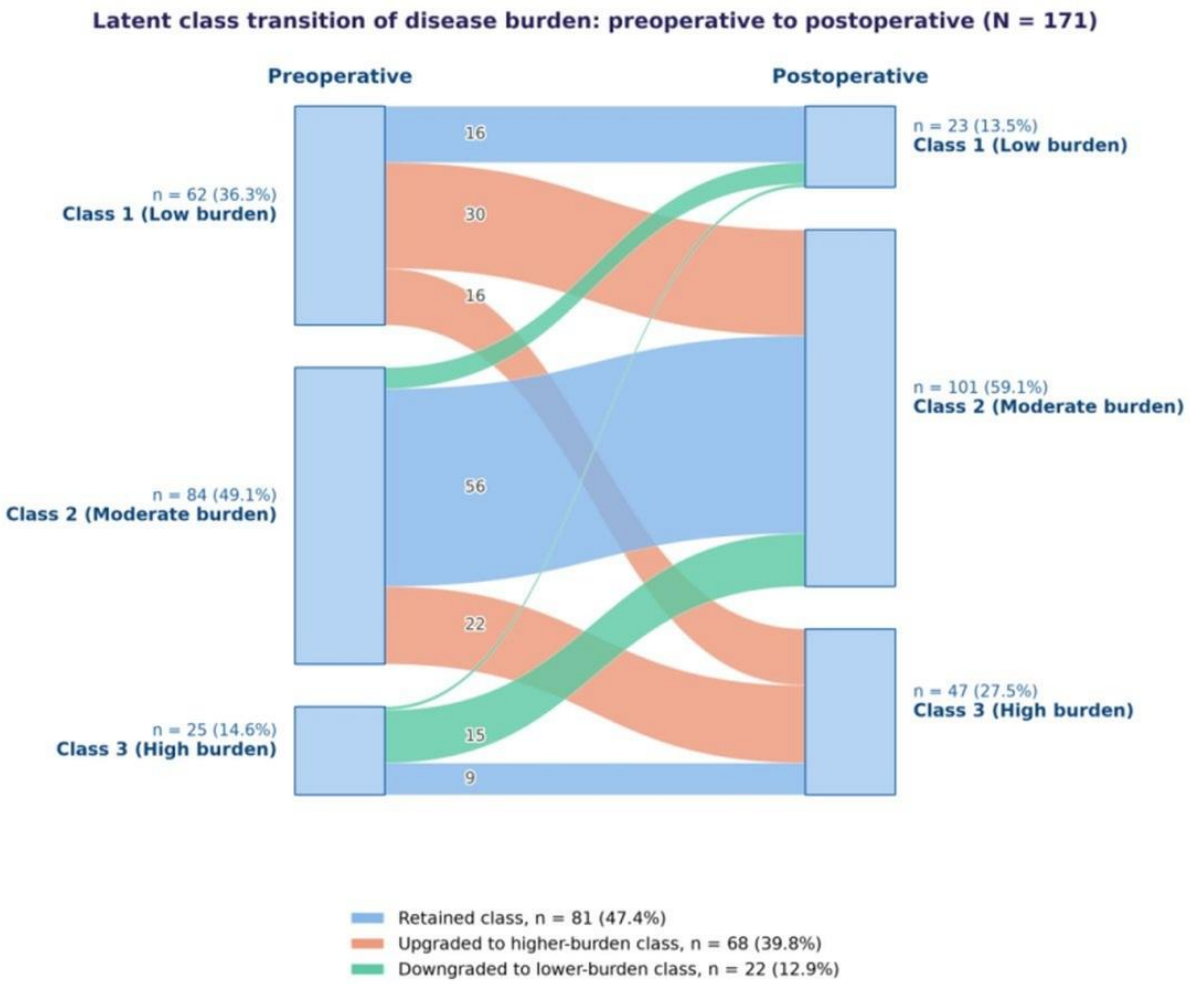


Figure 3. Latent class transition of preoperative and postoperative burden in patients with MMD (N = 171)

Analysis of the factors influencing burden outcome in patients with MMD

LTA results were used to define the outcome. Patients who moved from C1 at T1 to C2 or C3 at T2, from C2 to C2 or C3, or who stayed in C3 showed no improvement or a stable moderate-to-high burden and were coded as 1 (unfavourable outcome). The remaining patients were coded as 0 (favourable outcome). This group included patients whose class membership improved (C2 to C1; C3 to C1 or C2) and those who remained in C1 at both assessments. The C1-to-C1 transition involves no change in class but reflects a persistently

low symptom burden; thus, we treated it as a favourable outcome. A comparison of the 29 candidate variables between the two outcome groups is shown in Table 5. Age, sex, education, income and most disease and surgical characteristics were similarly distributed. Two variables distinguished the groups: a history of anxiety and depression (18.8% in the unfavourable group versus 36.8% in the favourable group, $\chi^2 = 5.467$, P = 0.019) and postoperative aphasia (21.8% versus 5.3%, $\chi^2 = 5.449$, P = 0.020). T1 Mutuality scores did not differ between the groups (44.5 versus 45.7, Z = −0.372, P = 0.711), nor was monthly income associated with the outcome ($\chi^2 = 6.216$, P = 0.104).

The three abovementioned variables were entered into the multivariable model (Table 6). A history of anxiety and depression was associated with lower odds of an unfavourable outcome (OR: 0.360, 95% CI: 0.158–0.820, P = 0.015), whereas postoperative aphasia increased the odds more than fivefold (OR: 5.387, 95% CI: 1.200–24.189, P = 0.028). A family history of MMD was not independently associated with the outcome (OR: 2.580, 95% CI: 0.697–9.555, P = 0.156). The model fit the data adequately (Hosmer-Lemeshow χ^2 = 7.749, df = 8, P = 0.458).

Table 6. Multivariable logistic regression analysis of unfavourable burden outcomes in patients with moyamoya disease (N = 171)

Variable	B	SE	OR	95% CI	P
History of anxiety and depression	-1.021	0.420	0.360	0.158, 0.820	0.015
Postoperative aphasia	1.684	0.766	5.387	1.200, 24.189	0.028
Family history of MMD	0.948	0.668	2.580	0.697,	0.156

	9.555

Discussion

We developed a multidimensional burden assessment framework based on the SPBS and GAD-7 and used LPA to characterise perioperative burden in patients with MMD. Burden was not uniform but fell into three classes (low, moderate and high burden) at both time points, with the emotional dimension exhibiting the greatest share of the total score at each point. More than half of the patients changed class between T1 and T2, and most of those changes were upward: the low-burden class fell from 36.3% to 13.5%, the high-burden class nearly doubled, and 77.8% of the cohort (133 patients) showed no improvement in class membership. Two factors accompanied this pattern. Postoperative aphasia was associated with more than fivefold higher odds of an unfavourable outcome (OR: 5.387, 95% CI: 1.200–24.189), whereas a documented history of anxiety or depression carried about two-thirds lower odds (OR: 0.360, 95% CI: 0.158–0.820). A family history of the disease showed no independent association. Perioperative burden was common in this population, and for most patients it persisted or worsened.

The imbalance across outcome groups warrants attention. Revascularisation restores perfusion; however, it does not eliminate the associated burden. Patients with unfavourable burden outcomes outnumbered those exhibiting improved burden by more than threefold (77.8% vs. 22.2%), and upward transitions outnumbered downward transitions (39.8% vs. 12.9%). All three T1 groups had shifted by T2. Specifically, the low-burden group decreased in number, the high-burden group nearly doubled, and 86.5% of patients were observed to be in the moderate or high group at discharge. Among the 62 patients who entered the

low-burden group, 46 transitioned into the moderate- or high-burden group at T2. A low burden at admission therefore offered little protection against a poorer course, and these patients are easily overlooked in practice. The moderate group was the largest and most stable group, with 56 patients (66.7%) remaining, whereas 22 progressed to the high-burden group. This stability left a substantial proportion of patients at a moderate burden throughout the study, possibly because they were psychologically better prepared and held more realistic expectations of surgery. Of the 25 patients in the high-burden group at T1, 16 (64%) improved, though the improvement was limited. Surgery diminished the most severe aspect of the psychological burden; it did not eliminate the burden itself.

The two factors differ in when they become observable, and this difference affects how each factor can be used. A documented history of anxiety or depression identifies patients who are already being treated. It can inform preoperative screening and preparation; however, it cannot capture undiagnosed mood problems. In contrast, postoperative aphasia is a complication recorded during the same hospital stay in which the T2 burden assessment was conducted. Its association with the outcome is concurrent rather than predictive: it identifies a group needing attention once aphasia has occurred, not a warning sign clinicians could act on earlier. Only two patients in the favourable group had aphasia, so the CIs are wide; the link nevertheless remains clinically plausible. Aphasia makes it more difficult for patients to express needs and to participate in the conversations and decisions associated with hospitalisation; consequently, increased frustration leads to more care load being shifted onto family members. Depression is markedly more common after stroke in aphasia patients than in healthy patients [17]; current rehabilitation guidelines treat psychosocial support as

integral to aphasia care [18]. In this study, patients with a history of anxiety or depression were less likely to have poor outcomes, the reverse of what would be expected. A likely reason is that these patients had been diagnosed before admission and were already receiving treatment or follow-up. Once detected at preoperative screening, they received more psychological support and counselling from medical staff and caregivers during the hospital stay. Mood disorders are common in MMD [19] but are often missed in routine practice [20]. Therefore, an apparent protective effect of a history of anxiety or depression may reflect only the difference between a managed burden in diagnosed patients and an unmanaged burden in others, as those who are never diagnosed with anxiety received neither treatment nor extra attention. GAD-7 anxiety scores were numerically higher after surgery, and 28.7% of patients scored 10 or above (the typical threshold for further evaluation). Thus, routine postoperative anxiety screening would detect more undermanaged patients than reliance on history alone.

In this study, we combined the GAD-7 with three burden dimensions (a design that was carefully considered). The SPBS captures the degree to which patients believe they are a burden to their caretakers. This construct overlaps with anxiety symptom severity but is not equivocal [21]. The two factors are correlated in chronic disease populations, wherein anxiety tends to amplify perceived burden [7]; however, one factor cannot replace the other. Family history was maintained in the model on clinical grounds (given the familial aggregation of the disease) [2], even though its confidence interval increased above a value of one. With only 24 affected patients, the study had limited power to detect a moderate effect. Any true effect may also be obscured by age at onset and disease severity, with neither factor being adjusted.

Currently, patient-reported outcomes in MMD have been primarily investigated in children [22]. Longitudinal data on the multidimensional burden of adult patients remain scarce, and most research on self-perceived burden considers it as a continuous variable, as examined through regression or mediation models [23]. Our LPA took the opposite route. Patients were grouped by their combined physical, emotional and financial burden rather than by total score, which avoids the arbitrary cut-offs that a single threshold imposes. This patient-centred strategy has proved useful in postoperative and chronic disease populations [24,25]. Applying the same analysis at T1 and T2 adds a further step, for which the transition itself becomes the outcome. Whether a patient moved towards a milder or heavier burden profile is a more natural unit for clinical assessment than a change of several points on a 10–50 scale, because it captures the direction of change, which is what care planning requires.

This study has several limitations. This was a single-centre study of moderate size, and disease burden was assessed through self-reports (a method that is sensitive to momentary moods and social desirability). No objective measures (such as cerebral haemodynamics) were included. Follow-up encompassed only the preoperative period and postoperative hospital stay; thus, the medium- and long-term course of burden after discharge could not be traced. The classify-then-analyse strategy also indicates that the profile structure still requires confirmation in an independent sample. In addition, the modest sample size, particularly the smallest preoperative class (n = 25), may have limited the precision of the transition probability estimates. Finally, the unfavourable-outcome definition was broad, as patients who remained in the moderate-burden class (C2 to C2, n = 56) were also counted as unfavourable; when only upward transitions were considered, 39.8% of patients worsened in

burden class (Table 4), so the 77.8% figure denotes an absence of improvement rather than uniform deterioration. In addition, the 10 excluded patients (4 not operated, 6 withdrawn for severe complications) differed from those analysed, so the findings may not generalise to patients with severe perioperative events. Given only two postoperative aphasia cases in the favourable group, the wide confidence interval for this estimate indicates that it should be interpreted with caution. The sample size was considered adequate for LPA and LTA given a small number of well-separated continuous indicators, as simulation studies show that such samples recover the correct number of classes when class separation is high [26,27].

For perioperative management, the findings support stratified care over a one-size-fits-all model. Screening should be initiated before surgery, with brief instruments such as the GAD-7 and the SPBS incorporated into the admission assessment; the low-burden group warrants the same attention as the others, as these patients are easily missed. For the moderate group, routine care alone is not enough. Psychological preparation, realistic framing of the extent of recovery, and open conversations about treatment costs address the main sources of burden for these patients. Postoperatively, patients with new-onset aphasia form a clearly bounded group who need early rehabilitation referral, adjusted communication strategies, and closer mood monitoring. Any patient exhibiting increased burden levels should receive a structured reassessment before discharge. Interventions should also be designed from a dyadic perspective, with patients and caregivers being connected through remote health education, psychological counselling, communication training, and multidisciplinary referrals; thus, the management of MMD can shift from a narrow focus on surgical care towards attention to the patient's burden across the whole course.

Conclusions

We followed 171 adults through elective revascularisation for MMD and grouped their self-perceived burden into low, moderate and high profiles at T1 and T2; most patients maintained their profile or transitioned to a higher-burden profile, and 77.8% were discharged without improvements in burden class. Postoperative aphasia identified the highest-risk patients, although a previous history of anxiety or depression was associated with better outcomes, most likely because these patients were already receiving treatment and closer attention. Brief preadmission burden and anxiety screening, closer monitoring of patients who develop aphasia and structured reassessment before discharge can help the perioperative team direct support to patients with the greatest needs, and larger multicentre studies with follow-ups extending beyond discharge are needed to track how the burden evolves after patients return home.

List of abbreviations

MMD: moyamoya disease

DSA: digital subtraction angiography

LPA: latent profile analysis

LTA: latent transition analysis

SPBS: self-perceived burden scale

GAD-7: generalized anxiety disorder-7

MS: Mutuality scale

mRS:Modified Rankin Scale

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Huashan Hospital, Fudan University (Approval No. KY2025-912). All participants were fully informed of the purpose and procedures of the study, participated voluntarily, and provided written informed consent. All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki and its later amendments.

Consent for publication

Written informed consent for the publication of their individual/clinical data was obtained from all participants included in this study.

Availability of data and materials

The data that support the findings of this study are not publicly available because they contain information that could compromise the privacy of participants. The datasets were collected under the approval of the Ethics Committee of Huashan Hospital, Fudan University (Approval No. KY2025-912), and the informed consent obtained from participants did not authorize public data sharing. De-identified data are available from the corresponding author, Chen Wei (yechen@huashan.org.cn), upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Clinical trial number

Not applicable.

Authors' contributions

JL* and DHL: Conceptualization, Methodology, Investigation, Data collection, Formal analysis, Writing – original draft. ZXF, CFY: Sample collection, Data curation, Data verification, Visualization. JQQ: Clinical case screening, Patient information collection and organization, Clinical data verification. WC* and ZLH: Project administration, Supervision, Writing – review & editing, Final approval. All authors read and approved the final manuscript, consented to publication, and agreed to be accountable for the accuracy and integrity of the work.

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References

1. Demartini Z Jr, Teixeira BC, Koppe GL, Gatto LAM, Roman A, Munhoz RP. Moyamoya disease and syndrome: a review. Radiol Bras. 2022;55(1):31-7. doi:10.1590/0100-3984.2021.0010.
2. Yoshimoto T, Okune S, Tanaka S, Yamagami H, Matsumaru Y. RNF213-related vasculopathy: an entity with diverse phenotypic expressions. Genes (Basel). 2025;16(8):939. doi:10.3390/genes16080939.
3. Sun Y, Zhou G, Feng J, Chen L, Liu G, Wang J, et al. Incidence and prevalence of moyamoya disease in urban China: a nationwide retrospective cohort study. Stroke Vasc Neurol. 2021;6(4):615-23. doi:10.1136/svn-2021-000909.
4. Gonzalez NR, Amin-Hanjani S, Bang OY, Coffey C, Du R, Fierstra J, et al. Adult moyamoya disease and syndrome: current perspectives and future directions: a scientific statement from the American Heart Association/American Stroke Association. Stroke. 2023;54(10):e465-e479. doi:10.1161/STR.0000000000000443.
5. Ihara M, Yamamoto Y, Hattori Y, Liu W, Kobayashi H, Ishiyama H, et al. Moyamoya disease: diagnosis and interventions. Lancet Neurol. 2022;21(8):747-58. doi:10.1016/S1474-4422(22)00165-X.
6. D'Angelo S, Kirsch S, Shenkar E, Khavjou O, Giombi K. Differences in patient-centered burdens and economic outcomes based on sociodemographic characteristics and social

determinants of health: a scoping review. Front Public Health. 2026;14:1784571. doi:10.3389/fpubh.2026.1784571.

7. Ye YY, Tao LF, Yang YL, Wang YW, Yang XM, Xu HH. Correlation between anxiety, depression, self-perceived burden, and psychological resilience in patients with chronic renal failure on maintenance hemodialysis. World J Psychiatry. 2025;15(7):103850. doi:10.5498/wjp.v15.i7.103850.

8. Ni W, Su J, Fei Y, Gu Y, Mao Y, Wang S, et al. Chinese expert consensus on the treatment and diagnosis of moyamoya disease and moyamoya syndrome (2024). Stroke Vasc Neurol. 2026;11(4):406-14. doi:10.1136/svn-2024-003925.

9. van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJ, van Gijn J. Interobserver agreement for the assessment of handicap in stroke patients. Stroke. 1988;19(5):604-7. doi:10.1161/01.STR.19.5.604.

10. Bahrami K, Sabi MS, Sasannejad P, Alavi-Kakhki SS, Abadi RNS, Ghandehari K. Prognostic value of the modified clot burden score in predicting outcomes of acute ischemic stroke patients. BMC Neurol. 2026 Feb 2;26(1):139. doi: 10.1186/s12883-026-04626-w.

11. Cousineau N, McDowell I, Hotz S, Hébert P, Achber L. Measuring chronic patients' feelings of being a burden to their caregivers: development and validation of a scale. Med Care. 2003;41(1):110-8.

12. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch Intern Med. 2006;166(10):1092-7.

13. van Ierssel JJ, Kutcher SA, Johnston S, Pham NK, Lamoureux M, Dodd AB, Mullan M, Yeates KO, Ledoux AA, Liu BC, Lalonde C, Master CL, Howell DR, Chintoh A, Mikolić A, Beauchamp MH, Silverberg ND, Zemek R; TRANSCENDENT Concussion Integrated Discovery Program. Prevalence and Risk of Anxiety and Depression after Concussion: A TRANSCENDENT Study. J Neurotrauma. 2026 Aug;43(15-16):1259-1270. doi: 10.1177/08977151261416446. Epub 2026 Feb 1.
14. Tong X, An D, McGonigal A, Park S-P, Zhou D. Validation of the Generalized Anxiety Disorder-7 (GAD-7) among Chinese people with epilepsy. Epilepsy Res. 2016;120:31-6.
15. Archbold PG, Stewart BJ, Greenlick MR, Harvath T. Mutuality and preparedness as predictors of caregiver role strain. Res Nurs Health. 1990;13(6):375-84.
16. Liu JY. A study on the relationship between family caregivers with dementia and the role of caregiving activities [PhD thesis]. Taoyuan: Chang Gung University; 2006. (Chinese).
17. Vogel-Eyny A, Jung YJ, Hyun J, Siegle E, Haroun A, et al. Prevalence of depression in post-stroke aphasia: systematic review and meta-analysis. BMC Neurol. 2025;26(1):43.
18. Brady MC, Mills C, Prag Øra H, Novaes N, Becker F, Constantinidou F, et al. European Stroke Organisation (ESO) guideline on aphasia rehabilitation. Eur Stroke J. 2025;10(4):1189-220.
19. Cao L, Liu E, Yuan X, Dong Y, Yang B, Li H. Clinical characteristics and potential pathology of moyamoya disease combined with psychiatric disorders in Chinese population: a cross-sectional study. J Affect Disord. 2025;381:1-8.
20. Oakley CI, Lanzino G, Klaas JP. Neuropsychiatric symptoms of moyamoya disease: considerations for the clinician. Neuropsychiatr Dis Treat. 2024;20:663-9.

21. Bigger SE, Vo T. Self-perceived burden: a critical evolutionary concept analysis. J Hosp Palliat Nurs. 2022;24(1):40-9.
22. Ahmad SA, Gatti JR, Peterson RK, Burton N, Malone LA, Sun LR. Patient-reported outcomes in childhood moyamoya arteriopathy. Pediatr Neurol. 2025;162:69-75.
23. Ren N, Ma F, Tian M, Zhang G, Xing Q, Zheng X, et al. The relationship between facilitation of patient involvement and self-perceived burden in postoperative lung cancer patients: the mediating role of social support. Patient Prefer Adherence. 2024;18:1979-89.
24. Chen Q, Jia Y, Li H, Lv S, Du T, Feng A. Self-perceived burden in elderly patients with chronic co-morbidities: a latent profile analysis. Front Psychol. 2025;16:1601198.
25. Huang W, Wu Q, Zhang Y, Zhu H. Latent profile analysis of health-related quality of life and its associated factors in postoperative aortic dissection patients: a cross-sectional study. Health Qual Life Outcomes. 2025;23(1):60.
26. Nylund-Gibson K, Choi AY. Ten frequently asked questions about latent class analysis. Transl Issues Psychol Sci. 2018;4(4):440-61.
27. Tein JY, Coxe S, Cham H. Statistical power to detect the correct number of classes in latent profile analysis. Struct Equ Modeling. 2013;20(4):640-57.

Table 5. Univariate analysis of unfavourable burden outcomes in patients with moyamoya disease (N = 171)

Variable	Category	Unfavourable outcome group (n = 133), n (%)	Favourable outcome group (n = 38), n (%)	χ^2/Z	P
Sex	Male	72 (54.1)	21 (55.3)	0.015	0.902

	Female	61 (45.9)	17 (44.7)		
Education level	Primary school	18 (13.5)	5 (13.2)	3.362	0.326b
	Secondary school	66 (49.6)	16 (42.1)		
	College	43 (32.3)	17 (44.7)		
	Above college	6 (4.5)	0 (0.0)		
Marital status	Married	124 (93.2)	35 (92.1)	0.058	0.730a
	Single	9 (6.8)	3 (7.9)		
Employment status	Employed	88 (66.2)	22 (57.9)	0.881	0.348
	Unemployed or retired	45 (33.8)	16 (42.1)		
Monthly income (CNY)	< 5000	62 (46.6)	22 (57.9)	6.216	0.104b
	5001–10000	51 (38.3)	10 (26.3)		
	10001–20000	11 (8.3)	6 (15.8)		
	> 20000	9 (6.8)	0 (0.0)		
Payment method	Medical insurance	124 (93.2)	36 (94.7)	0.111	1.000a
	Self-paid	9 (6.8)	2 (5.3)		
Family history of MMD	Yes	21 (15.8)	3 (7.9)	1.527	0.217
	No	112 (84.2)	35 (92.1)		
History of hypertension	Yes	62 (46.6)	13 (34.2)	1.847	0.174
	No	71 (53.4)	25 (65.8)		
History of anxiety and	Yes	25 (18.8)	14 (36.8)	5.467	0.019

depression					
	No	108 (81.2)	24 (63.2)		
Diagnosis type	Ischaemic	97 (72.9)	26 (68.4)	0.298	0.585
	Haemorrhagic	36 (27.1)	12 (31.6)		
Lesion side	Left	73 (54.9)	21 (55.3)	0.002	0.967
	Right	60 (45.1)	17 (44.7)		
Surgical procedure	Bypass	3 (2.3)	2 (5.3)	0.977	0.738b
	Bypass + synangiosis	103 (77.4)	28 (73.7)		
	Synangiosis	27 (20.3)	8 (21.1)		
Intraoperative blood loss (mL)	< 50	61 (45.9)	21 (55.3)	2.245	0.341b
	50–100	9 (6.8)	4 (10.5)		
	100–200	63 (47.4)	13 (34.2)		
Preoperative stroke	Yes	108 (81.2)	30 (78.9)	0.097	0.756
	No	25 (18.8)	8 (21.1)		
Preoperative epilepsy	Yes	7 (5.3)	0 (0.0)	2.085	0.351a
	No	126 (94.7)	38 (100.0)		
Preoperative limb impairment	Yes	23 (17.3)	4 (10.5)	1.018	0.313
	No	110 (82.7)	34 (89.5)		
Preoperative dysphagia	Yes	1 (0.8)	0 (0.0)	0.287	1.000a

	No	132 (99.2)	38 (100.0)		
Preoperative sleep disorder	Yes	12 (9.0)	6 (15.8)	1.437	0.238a
	No	121 (91.0)	32 (84.2)		
Postoperative stroke	Yes	9 (6.8)	0 (0.0)	2.714	0.210a
	No	124 (93.2)	38 (100.0)		
Postoperative hyperperfusion	Yes	29 (21.8)	9 (23.7)	0.060	0.806
	No	104 (78.2)	29 (76.3)		
Postoperative epilepsy	Yes	4 (3.0)	1 (2.6)	0.015	1.000a
	No	129 (97.0)	37 (97.4)		
Postoperative aphasia	Yes	29 (21.8)	2 (5.3)	5.449	0.020
	No	104 (78.2)	36 (94.7)		
Postoperative limb impairment	Yes	13 (9.8)	1 (2.6)	2.006	0.198a
	No	120 (90.2)	37 (97.4)		
Postoperative dysphagia	Yes	5 (3.8)	0 (0.0)	1.472	0.588a
	No	128 (96.2)	38 (100.0)		
Postoperative sleep disorder	Yes	65 (48.9)	19 (50.0)	0.015	0.902
	No	68 (51.1)	19 (50.0)		
Age (years)	Mean ± SD	45.11 ± 9.60	43.26 ± 10.40	0.840	0.402c
Time from	Mean ± SD	9.02 ± 8.39	10.76 ± 9.73	-0.661	0.510c

initial symptom to diagnosis (months)					
Mutuality score (T1)	Mean ± SD	44.53 ± 11.14	45.66 ± 9.99	-0.372	0.711c
Preoperative mRS score	Mean ± SD	0.95 ± 0.39	0.89 ± 0.31	0.810	0.420c

Note: a Fisher's exact test. b Monte Carlo exact test (20,000 replicates). c Mann-Whitney U test (Z value reported).