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A High Burden of 10 or More Clinically Asymptomatic Lesions Suppresses Neurocognitive Improvement 6 Months After Endovascular Coiling for Unruptured Intracranial Aneurysms

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Abstract

Objective

Endovascular coiling (EC) for unruptured intracranial aneurysms (UIAs) aims to safely prevent rupture while preserving cortical functions. However, newly developed silent embolic lesions are frequently captured on postprocedural diffusion-weighted imaging (DWI). This study evaluated how these subclinical lesions influence subsequent longitudinal neurocognitive trajectories using comprehensive psychometric batteries.

Methods

We retrospectively analyzed 26 consecutive patients who underwent EC for UIAs and completed detailed neurocognitive assessments both preoperatively and 6 months postoperatively. Neuroimaging was conducted using a 3-Tesla system, with DWI strictly obtained both on the immediate preprocedural day and on postoperative day 1 to count newly developed microlesions. Neuropsychological trajectories were evaluated via the WAIS-III and WMS-R batteries. Patients were stratified into the Low-Load (0 to 9 lesions, n = 16) and the High-Load (10 or more lesions, n = 10) groups.

Results

Cross-sectional inter-group comparisons revealed no statistically significant differences between the two cohorts. However, a critical disparity was unveiled during longitudinal intra-group analyses from baseline to 6 months. The Low-Load group demonstrated significant improvements across multiple cognitive domains, capturing score elevations in the PIQ (p = 0.0004), composite memory (p = 0.046), and average scores (p = 0.013). In contrast, these longitudinal improvements were abolished in the High-Load group (PIQ, p = 0.477; memory, p = 0.315; average, p = 0.131).

Conclusion

While EC achieves excellent overall safety, a postprocedural DWI lesion count ≥ 10 is significantly associated with suboptimal neurocognitive recovery, counteracting the expected longitudinal practice effect. Neurointerventionalists should maintain strict embolic protection to ensure subclinical cognitive safety.

Introduction

Endovascular coiling (EC) has become a widely accepted and highly effective treatment modality for unruptured intracranial aneurysms (UIAs) [1]. Because the primary therapeutic objective of treating UIAs is exclusively a preventive strategy to eliminate the long-term risk of subarachnoid hemorrhage, the

clinical margin for procedural complications is extremely narrow. Consequently, the ultimate gold standard for successful intervention has shifted beyond simple anatomical occlusion, demanding the absolute preservation of a patient's preprocedural neurological and functional status.

Despite major advancements in neurointerventional devices and techniques, newly developed ischemic microlesions are frequently detected on postprocedural diffusion-weighted imaging (DWI). Recent sensitive imaging protocols have revealed that the incidence of these post-coiling embolic events can reach up to approximately 80% to 90% [2]. Because the vast majority of these microlesions do not induce acute, focal neurological deficits like hemiparesis or aphasia during the immediate postoperative phase, they are traditionally classified as asymptomatic or silent embolic events. However, the potential latent impact of these acute embolic insults on subclinical cognitive networks remains a substantial source of concern within neurovascular care [3].

To date, previous studies investigating the impact of EC on postoperative neurocognitive outcomes have yielded conflicting results, with some reporting preserved cognitive status and others identifying temporal declines [4–7]. Consequently, the precise relationship between postprocedural silent embolic burden and subsequent neurocognitive profiles remains unclear, largely because historical literature heavily relied on simplified neurocognitive tests that lack diagnostic sensitivity. Although implementing extensive neuropsychological testing is highly impractical in routine clinical practice due to time constraints and institutional limits, detailed assessments are indispensable to capture subtle cognitive fluctuations. To address this gap, expanding upon our long-standing clinical and research experience in analyzing surgical impacts on cognitive performance, the present study utilized comprehensive Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) and Wechsler Memory Scale-Revised (WMS-R) batteries [8–12]. Furthermore, while a recent large-scale study demonstrated that a high embolic burden of 10 or more DWI lesions was significantly associated with a decline in neurocognitive performance in one month, its mid- to long-term impact remains to be fully elucidated [13]. Therefore, by stratifying our cohort based on this established threshold of postprocedural microlesion counts, we aimed to evaluate how a high silent embolic burden influences longitudinal neurocognitive outcomes at 6 months postoperatively.

Material and Methods

This retrospective, single-center study was approved by the institutional review board at Fuji Brain Institute and Hospital, and written comprehensive informed consent for the use of clinical and imaging datasets was obtained from all patients. Between April 2017 and December 2021, a series of patients underwent EC for UIAs at our institution. Among these, we included patients who completely underwent detailed neurocognitive assessments both preoperatively and at 6 months or more postoperatively. A total of 26 consecutive patients met these criteria and were included in the final analysis. Demographics, clinical information, MRI, DSA, neuropsychological examination, and follow-up findings were analyzed.

The embolization technique, including simple coiling, the double-catheter technique, balloon-assisted coiling, or stent-assisted coiling, was selected based on the anatomical characteristics of the aneurysm and the treatment strategy. All procedures used general anesthesia. Proper dual antiplatelet therapy was administered in all cases. Preoperative aneurysm size was measured as the maximum diameter on DSA.

The MRI examinations were performed using a 3.0 Tesla system (MAGNETOM Skyra; Siemens Healthineers, Erlangen, Germany). To evaluate new post-procedural ischemic events, DWI was acquired using a single-shot, spin-echo echo-planar imaging sequence with the following parameters: b-values of 0 and 1000 s/mm², repetition time of 6000 ms, echo time of 66 ms, slice thickness of 6 mm, a 0.9-mm intersection gap, matrix size of 130 x 130, and a 220-mm field of view. Diffusion gradients were successively applied in three orthogonal directions, with a total acquisition time of 54 seconds. Trace images were subsequently generated, and apparent diffusion coefficient maps were calculated using dedicated software. DWI was strictly obtained both on the immediate preoperative day and on postoperative day 1 (POD 1) in all cases. The presence of new high-signal lesions on DWI was evaluated by a neurointerventionalist who did not directly participate in the treatment, with exact counts determined up to 9 and grouped as 10 or more for stratification. To investigate the clinical impact of microischemic lesion burden, patients were stratified into two groups based on the postprocedural DWI lesion count.

Neuropsychological examinations were performed with the Japanese version of the WAIS-III and WMS-R by experienced speech therapists or by psychotherapists [14, 15]. These evaluators were aware of the fact that the patients had undergone EC but were unaware of the postoperative clinical course and the findings of postoperative MRI. Verbal (VIQ) and performance intelligence quotients (PIQ) were obtained from the WAIS-III. The composite memory score and attention/concentration score were obtained from the WMS-R. Averages of these scores were also calculated. The upper limit of age is 74 years to convert scores of subtests into age-matched standardized scores in the WMS-R. Therefore, the scores of subtests of each patient older than 75 years were converted into standardized scores using the conversion table for the 70- to 74-year-old age group that is derived from the general population [16]. Preoperative neuropsychological examinations were performed within 1 week before the surgery, and postoperative examinations were performed approximately 6 months after the surgery [10]. Follow-up MRI assessments were conducted concurrently at this 6-month postoperative visit.

The study tried to determine the net result of various factors associated with EC at 6 months postoperatively using group rate analysis. Continuous variables are expressed as medians with ranges/interquartile ranges or as means ± standard deviations. Following the classification used in a previous large-scale study, patients were stratified into the Low-Load (0–9 lesions) group and the High-Load (≥ 10 lesions) group to evaluate the impact of postprocedural microischemic burden [13]. To evaluate the clinical impact of postprocedural microischemic burden, the Wilcoxon signed-rank test was used to analyze longitudinal intra-group changes between preoperative and postoperative neurocognitive scores within each cohort stratified by the DWI lesion count. Inter-group comparisons of the preoperative and postoperative neurocognitive scores, patient demographics, and procedural characteristics between

the two groups were evaluated using the Wilcoxon rank-sum test or Fisher's exact test. Two-sided p values of less than 0.05 were considered significant. Statistical analysis was performed using JMP Student Edition 19 (SAS Institute, Inc., Cary, NC).

Results

Patient characteristics, aneurysm features, and procedural factors are detailed in Table 1. The total cohort exhibited a mean age of 62.4 ± 12.5 years, comprising 62.3 years in the Low-Load group (0–9 lesions, n = 16) and 62.6 years in the High-Load group (≥ 10 lesions, n = 10). Hereafter, parameters are presented for the total cohort, followed by the respective values for the Low-Load and High-Load groups in parentheses. Representative cases from both the Low-Load and High-Load groups are illustrated in Fig. 1.

Table 1
Patient Demographics, Aneurysm Characteristics, and Procedural Factors

Clinical Parameters	**Total Cohort (n = 26)**	**Low-Load Group (0–9 lesions, n = 16)**	**High-Load Group (≥ 10 lesions, n = 10)**	**p Value***
Patient Characteristics				
Age (years), mean ± SD	62.4 ± 12.5	62.3 ± 12.6	62.6 ± 13.0	0.916
Female gender, n (%)	20 (76.9)	12 (75.0)	8 (80.0)	1.000
Comorbidities & Risk Factors, n (%)				
Hypertension	23 (88.5)	14 (87.5)	9 (90.0)	1.000
Diabetes mellitus	1 (3.9)	1 (6.3)	0 (0.0)	1.000
Dyslipidemia	14 (53.9)	10 (62.5)	4 (40.0)	0.422
Smoking history	13 (50.0)	9 (56.3)	4 (40.0)	0.688
Drinking habit	6 (23.1)	5 (31.3)	1 (10.0)	0.352
Aneurysm Features				
Size (mm), mean ± SD	6.1 ± 1.5	6.5 ± 1.6	5.7 ± 1.3	0.170
Anterior circulation, n (%)	16 (61.5)	9 (56.3)	7 (43.8)	0.683
Acom	3	3	0	
IC-Achor	1	1	0	
IC-PC	3	2	1	
IC C2	9	3	6	
Approach side in anterior circulation, n				0.106
Left	11	8	3	
Right	5	1	4	
Posterior circulation, n (%)	10 (38.5)	7 (70.0)	3 (30.0)	0.683
BA tip	6	4	2	
BA-SCA	1	1	0	
VA	3	2	1	
Procedural Factors				

Clinical Parameters	Total Cohort (n = 26)	Low-Load Group (0–9 lesions, n = 16)	High-Load Group (≥ 10 lesions, n = 10)	p Value*
Operation time (min), mean ± SD	133.2 ± 31.4	141.4 ± 28.8	120.0 ± 32.3	0.061
Stent-assisted coiling, n (%)	9 (34.6)	5 (55.6)	4 (44.4)	0.482
Balloon-assisted coiling, n (%)	17 (65.4)	9 (52.9)	8 (47.1)	0.399
Number of coils, mean ± SD	6.0 ± 2.5	6.9 ± 2.6	4.6 ± 1.6	0.016

SD, standard deviation; n, number; Acom, anterior communicating artery; IC-Achor, internal carotid-anterior choroidal artery; IC-PC, internal carotid-posterior communicating artery; IC C2, internal carotid artery C2 segment; BA, basilar artery; BA-SCA, basilar artery-superior cerebellar artery; VA, vertebral artery.

* Significant at $p < 0.05$

Female gender was observed in 20 patients (76.9% total; 12 and 8 patients). Regarding comorbidities and risk factors, hypertension was present in 23 patients (88.5% total; 14 and 9 patients), diabetes mellitus was noted in 1 patient (3.9% total; 1 and 0 patients), dyslipidemia in 14 patients (53.9% total; 10 and 4 patients), smoking history in 13 patients (50.0% total; 9 and 4 patients), and drinking habits in 6 patients (23.1% total; 5 and 1 patient). These preprocedural baseline demographics and clinical risks exhibited equivalent distributions with no statistically significant differences between the two cohorts.

Anatomically, the mean preoperative aneurysm size was 6.1 ± 1.5 mm (6.5 ± 1.6 and 5.7 ± 1.3 mm). Aneurysms located in the anterior circulation comprised 16 cases (61.5% total; 9 and 7 cases). Within this anterior circulation cohort, specific locations comprised 3 anterior communicating artery (3 and 0 cases), 1 internal carotid-anterior choroidal artery bifurcation (1 and 0 cases), 3 internal carotid-posterior communicating artery bifurcation (2 and 1 cases), and 9 internal carotid artery C2 segment aneurysms (3 and 6 cases). The surgical approach side for these anterior lesions involved 11 cases on the left (8 and 3 cases) and 5 on the right (1 and 4 cases). Lesions in the posterior circulation comprised 10 cases (38.5% total; 7 and 3 cases), consisting of 6 basilar artery tip (4 and 2 cases), 1 basilar-superior cerebellar artery bifurcation (1 and 0 cases), and 3 vertebral artery aneurysms (2 and 1 cases).

In terms of procedural factors, the mean operation time was 133.2 ± 31.4 minutes (141.4 ± 28.8 and 120.0 ± 32.3 minutes). Regarding the specific endovascular techniques, simple coiling was performed in 1 case (0 and 1 case) and the double-catheter technique alone in 1 case (1 and 0 case), a combined balloon and double-catheter technique in 1 case (1 and 0 cases), balloon-assisted coiling alone in 14 cases (8 and 6 cases), stent-assisted coiling alone in 7 cases (5 and 2 cases), and a simultaneous stent and balloon-assisted technique in 2 cases (0 and 2 cases). To evaluate the specific technological impact of each adjunctive modality, balloon-assisted and stent-assisted parameters were subsequently analyzed as overlapping but independent operational factors based on their total cumulative usage.

Overall, balloon assistance was implemented in 17 cases (65.4% total; 9 and 8 cases) and stent assistance was utilized in 9 cases (34.6% total; 5 and 4 cases). All of these radiological, anatomical, and device-related parameters showed no statistically significant inter-group differences. The mean number of deployed coils was 6.0 ± 2.5 in the overall cohort, showing a statistically significantly higher count in the Low-Load group (6.9 ± 2.6 coils) than in the High-Load group (4.6 ± 1.6 coils; $p = 0.016$).

All procedures were successfully completed under general anesthesia. Minor bleeding was detected on postoperative CT in 1 case (3.8% total; 1 and 0 case), and all remaining cases were treated without periprocedural radiological or technical complications, with no patients demonstrating newly developed acute neurological deficits during the periprocedural phase.

Postoperative DWI performed on POD 1 revealed new silent embolic lesions in 23 patients (88.5%). However, all of these patients remained completely neurologically asymptomatic during the acute periprocedural phase. The distribution of high signal lesion on DWI is summarized in Table 2.

Table 2
Distribution of high signal lesion on DWI

Number of Lesions	Number of Patients (%)
0	3 (11.5)
1	6 (23.1)
2	1 (3.8)
3	2 (7.7)
4	1 (3.8)
5	1 (3.8)
6	1 (3.8)
8	1 (3.8)
10 or more	10 (38.5)

The median interval between the preoperative and postoperative neuropsychological examinations was 6 months (interquartile range, 6 to 7 months). During this follow-up period, delayed symptomatic cerebral infarction occurred in 2 patients (7.7% total, 2 and 0 patients), though both cases manifested only minor symptoms without impacting their activities of daily living. Additionally, surgical clipping of a vertebral artery–posterior inferior cerebellar artery aneurysm was performed in 1 case during the period. Follow-up MRI assessments at the time of postoperative neuropsychological examination revealed no newly developed ischemic lesion except for the two cases mentioned above, and confirmed stable occlusion of the aneurysms without recanalization in all cases.

The detailed longitudinal and cross-sectional neurocognitive outcomes evaluated via the comprehensive neuropsychological batteries (WAIS-III and WMS-R) and their calculated averages are summarized in Table 3. In the preoperative baseline analysis, no statistically significant differences were observed between the Low-Load and High-Load groups across any of the five evaluated indices—VIQ, PIQ, Composite Memory score, Attention/Concentration score, and the Average—confirming that the baseline neurocognitive profiles were homogeneous between the two cohorts prior to endovascular treatment. Similarly, in the cross-sectional inter-group comparison at the 6-month postoperative follow-up, no statistically significant differences were captured between the Low-Load and High-Load groups in any of the parameters.

Table 3
Preoperative and Postoperative Neurocognitive Baseline and Longitudinal Trajectories

Neurocognitive Indices and Timing	Total Cohort (n = 26)	Low-Load Group (0–9 Lesions, n = 16)	High-Load Group (≥ 10 Lesions, n = 10)	Inter-group p Value*
WAIS-III: VIQ				
Preoperative baseline	96.0 (88.0-109.5)	96.0 (90.3-109.8)	96.5 (84.8-110.3)	0.732
Postoperative follow-up	101.5 (89.8-110.8)	103.5 (90.5–107.0)	96.0 (88.0-114.0)	0.895
Intra-group p value**	0.086	0.303	0.094	—
WAIS-III: PIQ				
Preoperative baseline	110.0 (92.0-119.3)	110.0 (94.0-120.1)	103.5 (89.0-119.3)	0.598
Postoperative follow-up	112.5 (101.3-123.5)	114.0 (108.3-122.8)	107.5 (89.8-125.8)	0.399
Intra-group p value**	0.0003	0.0004	0.477	—
WMS-R: Composite memory score				
Preoperative baseline	102.5 (90.3-110.3)	104.0 (96.5-108.8)	93.5 (80.5-116.3)	0.414
Postoperative follow-up	107.0 (94.0-115.3)	107.0 (95.3-114.3)	103.5 (84.0-118.5)	0.712
Intra-group p value**	0.030	0.046	0.315	—
WMS-R: Attention/Concentration score				
Preoperative baseline	101.0 (90.0-112.5)	100.0 (90.0-110.0)	107.5 (92.0-120.0)	0.245
Postoperative follow-up	107.5 (89.3–119.0)	106.5 (87.0-114.0)	112.0 (92.3–120.0)	0.356
Intra-group p value**	0.072	0.098	0.766	—
Average				
Preoperative baseline	103.4 (92.6-110.6)	104.4 (96.0-109.3)	98.5 (87.8-115.6)	0.895
Postoperative follow-up	106.6 (94.8-115.9)	107.1 (101.4-113.5)	104.8 (86.4-119.4)	0.937
Intra-group p value**	0.002	0.013	0.131	—

Neurocognitive Indices and Timing	Total Cohort (n = 26)	Low-Load Group (0–9 Lesions, n = 16)	High-Load Group (≥ 10 Lesions, n = 10)	Inter-group p Value*

Values are expressed as median (interquartile range). WAIS-III, Wechsler Adult Intelligence Scale-Third Edition; WMS-R, Wechsler Memory Scale-Revised; VIQ, verbal intelligence quotient; PIQ, performance intelligence quotient.

Average, (VIQ + PIQ + composite memory score + attention/concentration score) ÷ 4

* Cross-sectional inter-group p values between the Low-Load and High-Load groups evaluated by the Wilcoxon rank-sum test (Significant at $p < 0.05$)

** Longitudinal intra-group p values between preoperative and postoperative scores evaluated by the Wilcoxon signed-rank test (Significant at $p < 0.05$)

However, a critical disparity between the two cohorts was unveiled when analyzing the longitudinal intra-group changes from the preoperative baseline to the 6-month postoperative follow-up. The Low-Load group (n = 16) demonstrated statistically significant and clear improvements across multiple cognitive domains; highly significant score elevations were captured in the WAIS-III PIQ (median: 110.0 to 114.0, $p = 0.0004$), the WMS-R Composite Memory score (median: 104.0 to 107.0, $p = 0.046$), and the Average (median: 104.4 to 107.1, $p = 0.013$). In contrast, the High-Load group ($n = 10$) did not show any statistically significant longitudinal improvements or score elevations across all evaluated domains, with flat trajectories observed in the PIQ (median: 103.5 to 107.5, $p = 0.477$), the Composite Memory score (median: 93.5 to 103.5, $p = 0.315$), and the Average (median: 98.5 to 104.8, $p = 0.131$).

Discussion

The present study demonstrated that EC for UIAs can be performed with excellent clinical safety, successfully preventing subsequent aneurysmal rupture without inducing overt neurocognitive deterioration. However, a closer look at the longitudinal trajectories revealed that the clinical outcomes were more favorable in patients with a lower embolic burden. While the Low-Load group exhibited apparent postoperative score elevations at six months in the PIQ, the general memory index, and the composite average score, these upward trends were completely abolished in the High-Load group. Crucially, because the preoperative baseline capacities were completely homogeneous between the two cohorts, this longitudinal disparity cannot be attributed to pre-existing individual variations in intelligence. Rather, these findings suggest that while endovascular treatment generally preserves preprocedural status, a cumulative burden of ten or more silent ischemic microlesions poses a subclinical disadvantage to neural processing networks.

To date, clinical investigations on neurocognitive outcomes after EC for UIAs have yielded variable results, yet a majority suggest that this modality safely preserves higher cortical functions. Several studies have shown that endovascular treatment does not systematically impair long-term cognitive profiles. For instance, Preiss et al. evaluated 32 patients undergoing EC and demonstrated no significant

cognitive changes at the one-year follow-up, showing no significant differences compared to surgical clipping [4]. Srivatsan et al. evaluated 33 patients and demonstrated that neuropsychological performance remained unchanged at one and six months postoperatively compared to preoperative baselines [6]. Conversely, some investigators have captured a higher vulnerability during the acute phase. Caveney et al. reported that patients undergoing EC showed declines in choice reaction time and attention compared with healthy controls at two weeks after treatment, though these scores successfully returned to baseline levels within one year [7]. Furthermore, Kang et al. identified a high incidence of postoperative cognitive impairment, affecting 44% of cases at one week and 19% at four weeks postoperatively [5]. Intriguingly, while new acute DWI lesions were detected on the first postoperative day in 60% of their patients, they established no statistically significant correlation between the presence of these microlesions and subsequent neurocognitive status.

Aligning with previous literature, the overall neurocognitive outcomes in our total cohort indicated that EC safely preserves baseline status without inducing overt decline. However, while historical studies relied on simplified neurocognitive tests that often masked embolic impacts, we implemented WAIS-III and WMS-R batteries requiring two to three hours of testing per patient. This rigorous approach provided the high sensitivity necessary to stratify patients into Low-Load and High-Load groups based on their exact microlesion counts. Following the embolic burden classification reported in a previous large-scale clinical trial, we utilized a threshold of 10 or more DWI lesions to define the High-Load group [13]. Through this granular analysis, we successfully revealed that a high embolic burden of ten or more lesions acts as a latent disadvantage that suppresses the expected postoperative trajectory. In essence, our detailed methodology successfully exposed a critical subclinical boundary where a high embolic load results in a suboptimal neurocognitive performance that completely evades conventional, short screening methods.

To correctly interpret the neurocognitive basis of these results, it is essential to recognize the nature of the postoperative score changes captured at six months. The statistically significant score elevations observed in the Low-Load group across the PIQ, general memory index, and composite average scores do not represent an organic improvement in baseline brain function. Instead, these upward shifts reflect a standard longitudinal practice effect, where patients perform better due to familiarity with the test configuration, combined with the relief of preprocedural anxiety after successful treatment [17, 18].

In contrast, this expected practice effect was entirely abolished in the High-Load group, leaving a completely flat trajectory overall. When the total number of newly developed postprocedural microlesions reaches or exceeds the threshold of ten, a cutoff value previously shown to correlate with acute neurocognitive deterioration, their diffuse distribution across both gray and white matter structures likely causes a subclinical disruption of global neural networks [13, 19]. Even without causing acute focal deficits like hemiparesis or aphasia, this cumulative embolic burden impairs whole-brain processing efficiency and exhausts the functional cognitive reserve. Consequently, the presence of ten or more lesions acts as a measurable processing disadvantage that counteracts the normal practice effect, manifesting as a failure to achieve the expected postoperative recovery [20].

Regarding the procedural factors associated with embolic burden, the mean number of deployed coils was the only parameter that exhibited a statistically significant difference between the two cohorts in this study. Intriguingly, this count was significantly higher in the Low-Load group than in the High-Load group, meaning that patients with fewer deployed coils were more prone to developing silent microlesions. This counterintuitive finding may suggest the possibility that the embolic load is not simply determined by aneurysm size or the physical volume of foreign material introduced, but rather influenced by procedural nuances such as microcatheter manipulation difficulties. While our postprocedural DWI positivity rate of 88.5% appears high, it reflects the high sensitivity of our 3-Tesla MRI protocol that successfully captured millimeter-sized dots, which is consistent with recent meta-analyses reporting silent embolic incidences up to 80% to 90%. Crucially, no patients developed acute focal deficits, proving that these microlesions act as asymptomatic procedural fingerprints that do not compromise gross clinical safety unless their cumulative count exceeds the single-digit threshold. Therefore, neurointerventionalists must maintain strict embolic protection including appropriate device selection, the enforcement of continuous flushing systems, and gentle device deployment to ensure subclinical cognitive safety even in anticipated simple cases [21].

Several limitations of this study must be acknowledged, including its retrospective, single-center design and the small sample size of 26 patients. Furthermore, we could not evaluate the clinical impact of lesion locations (e.g., specific anatomical structures or vascular territories), as our limited sample size precluded a meaningful stratified analysis based on the precise distribution of microlesions. Additionally, we could not entirely isolate the potential confounding neurocognitive effects of minor secondary clinical events observed during the 6-month follow-up period, such as delayed symptomatic infarctions that occurred in two patients. However, both of these specific patients were ultimately stratified into the Low-Load group, meaning that these subsequent secondary events did not confound the flat cognitive trajectories exclusively observed within the High-Load cohort. The primary methodological strengths that offset these limitations include our rigorous neuroimaging protocol, where DWI was strictly performed on the immediate preprocedural day and postoperative day 1 to definitively ensure that all detected microlesions were acutely developed during the intervention rather than pre-existing. This precise radiological tracking was combined with the complete implementation of the comprehensive WAIS-III and WMS-R batteries, requiring 2 to 3 hours of testing per patient. This comprehensive approach ensured a high level of diagnostic accuracy and deep multi-domain sensitivity per individual, successfully exposing subclinical cognitive fluctuations that would typically escape conventional, simplified screening methods.

Conclusion

In conclusion, while EC for UIAs achieves excellent clinical and procedural safety, a postprocedural DWI lesion count of 10 or greater is significantly associated with suboptimal postoperative neurocognitive recovery at 6 months. Crucially, because preoperative neurocognitive baselines were completely homogeneous, this longitudinal trajectory disparity can be directly attributed to the cumulative burden of microischemic damage which counteracts the normal practice effect. Neurointerventionalists should

remain highly vigilant regarding the latent cognitive risks of multiple asymptomatic microinfarctions and strictly strive for maximized embolic protection including appropriate device selection, the enforcement of continuous flushing systems, and gentle device deployment to ensure a higher dimension of subclinical cognitive safety even in anticipated simple cases.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics Approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Fuji Brain Institute and Hospital (No. 202303).

Consent to Participate

Comprehensive informed consent was obtained from all individual participants included in the study as approved by the ethics committee.

Consent to Publish

The authors affirm that human research participants provided informed consent for the publication of all de-identified individual participant data included in this manuscript.

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Author Contribution

Design or conceptualization of the study: HO; Acquisition of data: HO, KO, YH, TH, TTs; Analysis or interpretation of the data: HO, SKi, SKo, AT; Writing - original draft: HO; Writing - review & editing: TI, SKo, AK, SM, MS, TTa, AT; Supervision: AT, NS. All authors have read and approved the final version of the manuscript.

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Figures

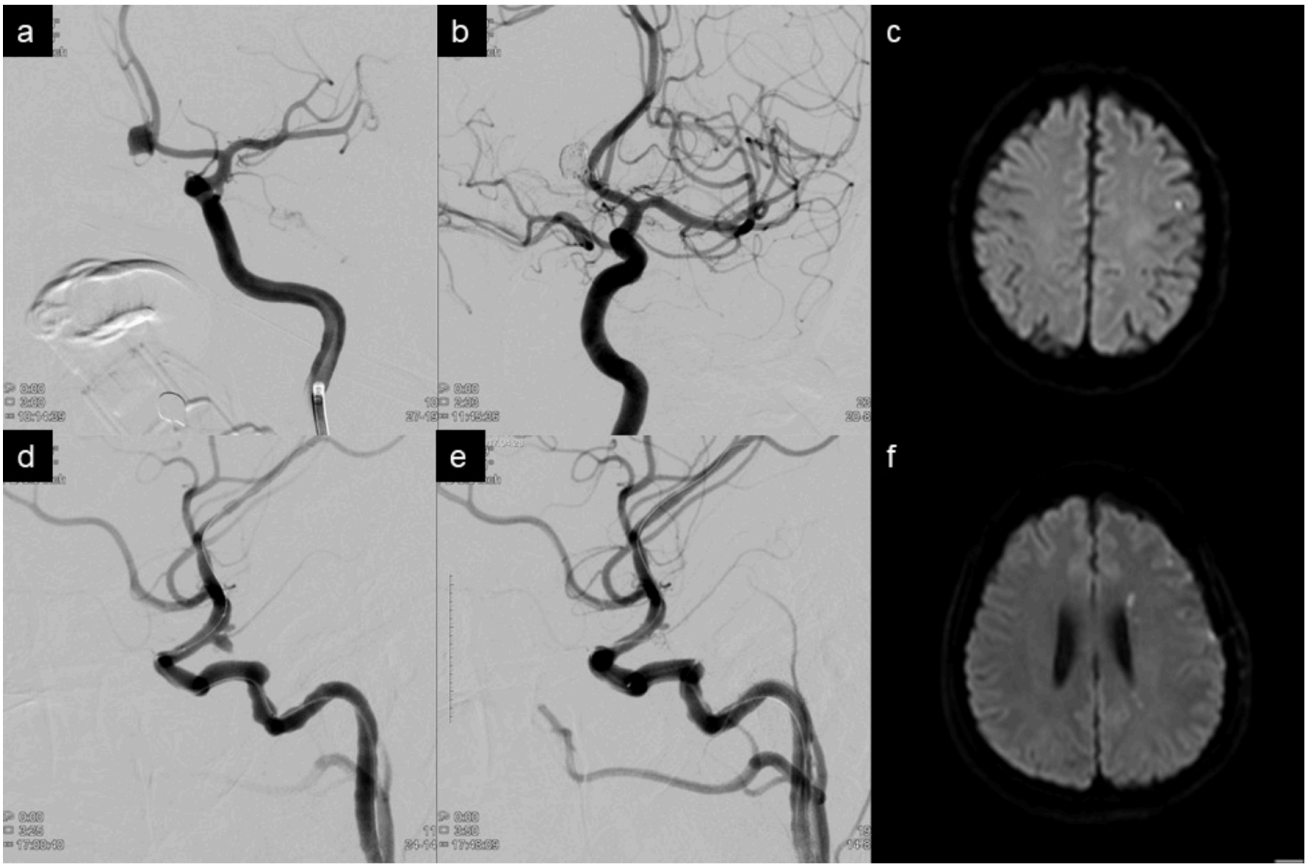


Figure 1

Representative cases from both the Low-Load and High-Load groups

a-c: Representative case of the Low-Load group with only one lesion. A 72-year-old man with a 10-mm anterior communicating artery aneurysm underwent stent-assisted coil embolization (a, b). Diffusion-weighted imaging (DWI) obtained on postoperative day (POD) 1 demonstrates a single high-signal intensity spot in the left frontal lobe (c).

d-f: Representative case of the High-Load group with ten or more lesions. A 40-year-old woman with a 5.2-mm left internal carotid-posterior communicating artery aneurysm underwent balloon-assisted coil embolization (d, e). DWI performed on POD 1 demonstrates diffusely scattered high-signal intensity spots within the left cerebral hemisphere (f).