

Does a Craniotomy for Treatment of Unruptured Aneurysm Affect Cognitive Function?

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Abstract

The surgical procedure used to treat an unruptured intracranial aneurysm (UIA) has controversial effects on cognitive function. From January 2010 through December 2012, we enrolled patients who underwent surgical clipping for a UIA. Patients were tested within one week prior to surgery and again postoperatively (6.8 ± 2.3 days) using a neuropsychological battery comprising the Mini-Mental State Examination, the Trail Making Test (TMT), the Frontal Assessment Battery (FAB), and Raven's colored progressive matrices (RCPM). Differences between preoperative and postoperative test scores for each examination were analyzed across individuals. In an additional subgroup analysis, patients were grouped according to age (< 65 or ≥ 65 years), the largest dimension of the aneurysm, the location of the aneurysm (i.e., anterior communicating artery, internal carotid artery, or middle cerebral artery) and operation duration. Paired student's *t*-tests were used to examine potential differences between groups. Two-tailed *P*-values < 0.05 were considered significant. Seventy-one patients were included in the analysis. The surgical procedure used to correct a UIA resulted in significant changes in neuropsychological scores. After the procedure, the TMT-A score declined significantly, whereas the FAB and RCPM scores were significantly improved. In the subgroup analysis, a significant deterioration in TMT-A score was observed in older patients and those with larger aneurysms, anterior communicating artery aneurysms and longer surgeries. Our findings, therefore, indicate that the surgical procedure to correct a UIA affects cognitive function. Older patients and those with large aneurysms, anterior communicating aneurysms, and long operations represent the high-risk groups.

Key words: unruptured aneurysm, cognitive function, neuropsychological test, surgical clipping

Introduction

Whether the surgical procedure used to correct an unruptured intracranial aneurysm (UIA) results in cognitive impairment remains controversial. Some studies have reported that this procedure disturbs cognitive function,^{1,2)} whereas others report that it does not,^{3,4)} and others even report the possibility of cognitive improvement.⁵⁾ To clarify these discrepant results, we performed a well-designed, large prospective study.

Materials and Methods

I. Design

This study was a single-center, prospective cohort study.

II. Subjects

All of the patients who were scheduled for clipping for a UIA between February 2010 and December 2012 were recruited. Exclusion criteria included previous neurosurgery, the presence of a symptomatic aneurysm and clipping with a high-flow bypass procedure. Patients were also excluded if they were unable to complete the neuropsychological tests due to postoperative severe disability or poor physical condition within the predetermined period. Patients were not excluded from testing if radiographical abnormalities such as strokes, contusions, or intracranial hemorrhages were demonstrated postoperatively. All of the patients were Asian. Neuropsychological evaluations were completed within one week prior to surgery and 6.8 ± 2.3 days after surgery. Patients were included consecutively during the study period to avoid selection bias. To avoid information bias, neuropsychological

tests were performed by speech-language pathologists who were not involved in the perioperative management of the patients. Informed consent was obtained from each patient in advance.

III. Neuropsychological tests

The evaluation included the following tests: (1) the Mini-Mental State Examination (MMSE),⁶⁾ a valid and reliable instrument widely used to assess global cognitive function. Higher scores indicate better function. (2) The Frontal Assessment Battery (FAB),⁷⁾ which consists of six subtests, each exploring one of the functions related to the frontal lobes (i.e., conceptualization, mental flexibility, motor programming, sensitivity to interference, inhibitory control). Higher scores indicate better function. (3) The Trail Making Test (TMT), which tests rapid visual search and executive functions such as visuospatial sequencing and cognitive set shifting. The TMT consists of two parts, A and B. Part A is primarily used to examine visual cognitive processing speed, whereas part B is used to examine executive functioning.⁸⁾ The score is the time needed to complete the task. Higher scores indicate worse function. (4) Raven's colored progressive matrices (RCPM), which test non-verbal intelligence based on visuospatial and analogical function. Higher scores indicate better function. The patients were evaluated postoperatively with the same battery of tests but indifferent forms to minimize practice effects. All of the neuropsychological evaluations were performed by speech-language pathologists who were not involved in the perioperative management of the patients.

IV. Surgical procedures

Of the 71 patients included in the analysis, 62 underwent frontotemporal (pterional) craniotomies, and 9 underwent inter-hemispheric approaches through frontal craniotomies for anterior communicating artery aneurysms. The pterional approach involved a frontotemporal incision, subfacial dissection of the temporal muscle, burr hole craniotomy with a CODMAN disposable perforator (14 mm) (Codman, Raynham, Massachusetts, USA) and a curvilinear dural opening. The interhemispheric approach involved a bicoronal incision, burr hole craniotomy with the perforator (14 mm), and a curvilinear dural opening. Of the 17 patients with anterior communicating artery aneurysm, 9 patients underwent clipping through the interhemispheric approach for anterior communicating artery aneurysm. The interhemispheric approach involved a bicoronal incision, burr hole craniotomy with the perforator (14 mm), and a curvilinear dural opening.

While approaching the aneurysm, the brain was protected with surgical cottons, the arachnoid was dissected sharply, and retraction of brain was minimized. After the clip was applied to the aneurysm, the motor evoked potential monitoring, the indocyanine green video-angiography, and Doppler flow study were used to confirm the patency of vessels.

V. Data analysis

Paired student's *t*-tests were used to analyze differences between preoperative and postoperative neuropsychological test scores. Two-tailed *p*-values < 0.05 were considered significant. In the subgroup analysis, patients were grouped according to age (< 65 or ≥ 65 years), the largest dimension of the aneurysm (< 5 or ≥ 5 mm), the location of the aneurysm (i.e., anterior communicating artery, internal carotid artery, or middle cerebral artery) and operation duration (< 300 or ≥ 300 min). A multivariable regression analysis was used to estimate the association between cognitive impairment and each subgroup. In this analysis, we compared patients who exhibited deterioration of a score by more than 2 standard deviation (SD) with those who exhibited no deterioration. The statistical analyses were performed using SPSS software (SPSS™; SPSS Inc., Chicago, Illinois, USA).

Ethics Approval

This study was approved by the NTT Medical Center Tokyo Research Ethics Committee (Authorization number 13-206).

Results

Eighty-eight patients underwent clipping for a UIA during the defined study period. Seventeen patients were excluded from the analysis: six patients with symptoms due to the mass effect of the aneurysm, three patients with a history of previous neurosurgeries, two patients who underwent clipping for an aneurysm via the bypass procedure and six patients whose cognitive function evaluation was not completed within the predetermined period. After exclusion, 71 patients (32 males and 39 females) were included in the study. The patient characteristics are shown in Table 1. The mean (\pm SD) age of the patients was 61.7 ± 10.3 years. The mean size (i.e., the largest dimension) of the aneurysm was 6.4 ± 2.8 mm. Patients included in the analysis did not have a history of diseases that influence cognitive function, such as stroke, complicated diabetes, or dementia. Postoperative neurological deficits were not evident among the

Table 1 Patients characteristics

	Location of the aneurysms				Overall
	ACom	IC	MCA	Others	
No. of cases	17	22	22	10	71
Age (years)	62 ± 10	62 ± 10	61 ± 11	61 ± 8	61.7 ± 10.3
Sex Male (%)	9 (53)	7 (32)	11 (50)	4 (40)	32 (45)
Female (%)	8 (47)	15 (68)	11 (50)	6 (60)	39 (55)
Operation duration (min)	316 ± 100	325 ± 64	281 ± 89	389 ± 137	313 ± 93
Largest dimension (mm)	6.1 ± 2.6	6.2 ± 2.4	6.2 ± 1.8	7.3 ± 1.5	6.3 ± 2.2

ACom: anterior communicating artery, IC: internal carotid artery, MCA: middle cerebral artery. Age, operation duration, and largest dimension are shown by mean ± standard deviation.

Table 2 Perioperative neuropsychological test score

Test	Score: mean ± SD (95% CI)				P value	No. of cases
	Pre		Post			
Overall						71
MMSE	28.0 ± 0.25	(28.0–29.0)	28.3 ± 0.4	(27.4–29.1)	0.62	
FAB	16.2 ± 0.2	(15.8–16.6)	16.5 ± 0.2	(16.2–16.9)	< 0.05	
TMT-A	103.8 ± 4.6	(95.0–113)	113.6 ± 4.6	(104.4–122.8)	< 0.01	
TMT-B	145.7 ± 6.7	(132.2–159)	147.7 ± 7.3	(133.1–162.3)	0.70	
RCPM	31.5 ± 0.6	(30.2–32.7)	32.2 ± 0.5	(31.2–33.2)	< 0.05	

MMSE: Mini-Mental State Examination, FAB: Frontal Assessment Battery, TMT: Trail Making Test, RCPM: Raven's colored progressive matrices, SD: standard deviation, CI: confidence interval.

patients included in the analysis. Computed tomography was performed in all cases the day after surgery. This analysis revealed a mild contusion in 6 cases, thin subdural hemorrhages without mass effects in 7 cases, and thin epidural hemorrhages without mass effects in 4 cases. Among the patients with a postoperative contusion, the preoperative and postoperative performances in each test were as follows: MMSE: 28.6 and 28.6; FAB: 16.6 and 17.0; TMT-A: 79.6 and 82.7; TMT-B: 111.6, and 111./6; RCPM: 31.3 and 34.0, respectively, without statistically significant differences ($P > 0.05$). Clipping for a middle cerebral artery aneurysm or an internal carotid aneurysm was conducted using the pterional approach. Clipping for an anterior communicating artery aneurysm was conducted with either the interhemispheric approach (9/17) or the pterional approach (8/17). All of the preoperative neuropsychological evaluations were completed within one week before surgery. Postoperative evaluations were completed within 6.8 ± 2.3 (5–12) days. Preoperative and postoperative performances in each test were as follows (Table 2): MMSE: 28.5 (95% confidence interval [CI]: 28.0–29.0) and 28.3 (95% CI: 27.4–29.1);

FAB: 16.2 (95% CI: 15.8–16.6) and 16.5 (95% CI: 16.2–16.9); TMT-A: 103.8 (95% CI: 95.0–113.0) and 113.6 (95% CI: 104.4–122.8); TMT-B: 145.7 (95% CI: 143.3–159.0) and 147.7 (95% CI: 133.1–162.3); RCPM: 31.5 (95% CI: 30.2–32.7) and 32.2 (95% CI: 31.2–33.2); respectively. The postoperative scores on the FAB ($P = 0.02$) and RCPM ($P = 0.03$) were significantly higher than the preoperative scores, whereas the postoperative score on the TMT-A ($P = 0.002$) was significantly higher than the preoperative score. These findings indicate a deterioration of cognitive function.

In the subgroup analysis, deterioration was observed after surgery in the TMT-A score in elderly patients ($P = 0.049$) as well as in patients with large aneurysms ($P = 0.042$), anterior communicating artery aneurysms ($P = 0.016$), and long operation durations. Deterioration of the TMT-A score in the anterior communicating artery aneurysm group was evident only in internal hemispheric approach cases ($P = 0.009$). In contrast, the FAB and RCPM scores showed improvement of cognitive function in older patients (FAB: $P = 0.049$; RCP: $P = 0.043$) and those with smaller aneurysms (FAB: $P = 0.004$; RCP: $P = 0.002$) (Tables 3 and 4).

Table 3 Subgroup analysis of perioperative neuropsychological test score

Subgroup	Test	Score: mean \pm SD (95% CI)		P value	No. of cases
		Pre	Post		
Age					
< 65 yr	MMSE	28.5 \pm 0.3 (27.9–29.1)	29.0 \pm 0.2 (28.5–29.4)	0.11	42
	FAB	16.8 \pm 0.1 (16.4–17.0)	17.0 \pm 0.2 (16.6–17.3)	0.42	
	TMT-A	92.9 \pm 3.4 (84.3–101.6)	99.7 \pm 4.6 (90.5–108.9)	0.06	
	TMT-B	126.9 \pm 1.0 (115.0–138.9)	126.3 \pm 7.2 (112.0–140.7)	0.90	
	RCPM	32.5 \pm 0.3 (31.1–33.1)	33.1 \pm 0.5 (32.1–34.1)	0.22	
\geq 65 yr	MMSE	28.2 \pm 0.6 (27.1–29.3)	28.0 \pm 0.6 (26.8–29.2)	0.75	29
	FAB	15.5 \pm 0.4 (14.6–16.3)	16.0 \pm 0.4 (15.4–16.7)	< 0.05	
	TMT-A	119.3 \pm 10.4 (98.6–140.0)	132.8 \pm 10.8 (112.0–153.6)	< 0.05	
	TMT-B	183.4 \pm 0.2 (182.9–183.8)	182.6 \pm 0.5 (181.6–183.5)	0.96	
	RCPM	29.6 \pm 1.1 (27.5–31.7)	30.7 \pm 1.1 (28.7–32.8)	< 0.05	
Largest dimension of aneurysm					
< 7 mm	MMSE	28.4 \pm 0.3 (27.8–29.0)	28.9 \pm 0.3 (28.4–29.4)	0.14	44
	FAB	16.2 \pm 0.3 (15.6–16.7)	16.7 \pm 0.2 (16.3–17.1)	< 0.01	
	TMT-A	102.1 \pm 5.2 (91.7–112.4)	109.2 \pm 0.8 (97.6–120.7)	0.07	
	TMT-B	141.6 \pm 8.1 (125.5–157.8)	143.4 \pm 8.5 (126.4–160.4)	0.78	
	RCPM	30.7 \pm 0.9 (28.9–32.5)	32.0 \pm 0.8 (30.5–33.6)	< 0.01	
\geq 7 mm	MMSE	28.5 \pm 0.5 (27.5–29.5)	28.3 \pm 0.6 (27.2–29.4)	0.71	27
	FAB	16.3 \pm 0.4 (15.6–17.0)	16.3 \pm 0.4 (15.5–17.0)	0.86	
	TMT-A	104.1 \pm 9.3 (85.4–122.7)	115.2 \pm 9.1 (96.9–133.4)	< 0.05	
	TMT-B	152.0 \pm 15.7 (118.6–185.3)	150.5 \pm 17.4 (115.4–185.3)	0.90	
	RCPM	32.5 \pm 0.7 (31.0–33.9)	32.5 \pm 0.6 (31.3–33.7)	0.94	

MMSE: Mini-Mental State Examination, FAB: Frontal Assessment Battery, TMT: Trail Making Test, RCPM: Raven's colored progressive matrices, SD: standard deviation, CI: confidence interval.

In addition, we evaluated the association between each factor and deterioration in the TMT-A score by comparing five patients who exhibited a reduction in TMT-A score of more than 2 SD of the mean (48 points) with 23 patients who did not exhibit such a reduction. This evaluation was performed using a multivariable regression analysis and included age, the largest dimension of the aneurysm, the location of the aneurysm (i.e., whether it was an anterior communicating artery aneurysm), and operation duration.

After multivariable regression analysis, no significant correlation was found for any factor. The P-values were as follows: the largest dimension of the aneurysm, $P = 0.057$; the location of the aneurysm, $P = 0.44$; age, $P = 0.60$; and operation time, $P = 0.70$. Of the factors analyzed, the size of the aneurysm exhibited a tendency to contribute to cognitive impairment.

Discussion

To our knowledge, this is the largest prospective study to show that the surgical procedure to correct an UIA has a significant effect on cognitive function.

In the overall analysis, the TMT-A score deteriorated after surgery, whereas the TMT-B score did not change significantly. The TMT is one of the most popular neuropsychological tests and is included in most test batteries. In our series, the TMT score significantly deteriorated in older patients (70.5 ± 6.1 years old). It is well-known that performance on the TMT is affected by age^{8,9)}; however, the post-operative TMT-A score (132.8 ± 10.4) in our series was worse than the normative score (84.6 ± 23.75) of 72 ± 1.4 year-old individuals.⁸⁾ The TMT-A requires an individual to draw lines sequentially connecting 25 numbers distributed on a sheet of

Table 4 Subgroup analysis of perioperative neuropsychological test score

Location of aneurysm				
Anterior communicating artery				
MMSE	28.2 ± 0.5 (27.3–29.1)	28.5 ± 0.5 (27.6–29.5)	0.42	17
FAB	16.3 ± 0.2 (15.9–16.7)	16.6 ± 0.2 (16.2–16.9)	0.09	
TMT-A	99.0 ± 1.7 (85.7–112.3)	115.8 ± 8.3 (99.1–132.4)	< 0.05	
TMT-B	154.4 ± 17.8 (118.8–190.0)	137.4 ± 12.3 (112.9–161.9)	0.15	
RCPM	31.5 ± 1.1 (29.3–33.7)	31.9 ± 1.1 (29.9–34.0)	0.65	
Internal carotid artery				
MMSE	27.8 ± 0.6 (26.6–29.0)	28.6 ± 0.5 (27.6–29.5)	0.07	23
FAB	15.7 ± 0.4 (15.0–16.5)	16.2 ± 0.3 (15.6–16.8)	< 0.01	
TMT-A	109.8 ± 9.2 (91.4–128.1)	115.9 ± 8.6 (98.8–133.0)	0.28	
TMT-B	147.0 ± 12.0 (123.1–171.0)	162.1 ± 15.8 (130.5–193.6)	< 0.05	
RCPM	31.2 ± 1.1 (29.0–33.3)	32.4 ± 0.8 (30.7–34.0)	0.07	
Middle cerebral artery				
MMSE	27.8 ± 0.6 (26.6–29.0)	28.6 ± 0.5 (27.6–29.5)	0.07	23
FAB	15.7 ± 0.4 (15.0–16.5)	16.2 ± 0.3 (15.6–16.8)	< 0.01	
TMT-A	109.8 ± 9.2 (91.4–128.1)	115.9 ± 8.6 (98.8–133.0)	0.28	
TMT-B	147.0 ± 12.0 (123.1–171.0)	162.1 ± 15.8 (130.5–193.6)	< 0.05	
RCPM	31.2 ± 1.1 (29.0–33.3)	32.4 ± 0.8 (30.7–34.0)	0.07	
Operation duration				
< 300 min				
MMSE	27.8 ± 0.5 (26.9–28.8)	28.5 ± 0.4 (27.7–29.2)	0.10	31
FAB	15.5 ± 0.4 (14.8–16.2)	15.8 ± 0.3 (15.3–16.4)	0.13	
TMT-A	121.6 ± 7.4 (106.8–136.3)	132.0 ± 7.3 (117.4–146.6)	0.09	
TMT-B	169.9 ± 11.9 (146.2–193.7)	178.8 ± 13.0 (152.7–204.8)	0.30	
RCPM	30.0 ± 1.0 (28.1–31.9)	31.0 ± 1.0 (29.2–32.9)	0.07	
≥ 300 min				
MMSE	29.0 ± 0.2 (28.6–29.4)	28.8 ± 0.3 (28.2–29.4)	0.53	40
FAB	16.8 ± 0.2 (16.3–17.2)	17.0 ± 0.2 (16.7–17.4)	0.09	
TMT-A	90.6 ± 4.5 (81.6–99.6)	99.9 ± 5.2 (89.6–110.2)	< 0.01	
TMT-B	127.6 ± 7.4 (113.0–142.3)	124.6 ± 5.9 (111.1–138.2)	0.65	
RCPM	32.4 ± 0.8 (30.8–33.9)	33.0 ± 0.6 (31.8–34.2)	0.19	

MMSE: Mini-Mental State Examination, FAB: Frontal Assessment Battery, TMT: Trail Making Test, RCPM: Raven's colored progressive matrices.

paper. The TMT-B is similar to the TMT-A except that it requires the person to alternate between numbers and letters (e.g., 1,A,2, B,3,C). Though these two tests are similar, the TMT-B score provides information on cognitive flexibility, executive functions, and working memory in addition to the visual search function and speed of processing, which are also assessed by the TMT-A. Therefore, the TMT-B score is affected by more factors and is less specific to deterioration of the visual search function than the TMT-A. We observed deterioration after surgery only

in the TMT-A, which might suggest that the negative effect of surgical clipping for UIA on cognitive function is specific to the visual search function.^{10–13} In fact, the FAB score, which provides information about mental flexibility and motor programming, was improved after surgery.

In our series, FAB and RCPM scores showed the opposite trend after surgery (i.e., improvement) than the TMT-A score. This should be interpreted not as a discrepancy but rather a reflection of the multiphasic character of the effect of the surgical

procedure on cognitive function.

Ohue et al.¹⁾ reported a deterioration of cognitive function in tests of executive function and memory. In contrast, Kubo et al.⁵⁾ reported an improvement of cognitive function after clipping for a UIA. These authors observed an improvement of scores on the intelligence quotient and the Rey-Osterrieth complex figure test, which agrees with our findings of improved intelligence based on visuoperceptual and analogical functions.

Identifying the reason for the perioperative changes in cognitive function after clipping for a UIA is beyond the scope of our study, but a possible cause for the improvement of cognitive function is relief from anxiety. According to Haug et al.,¹⁴⁾ patients with an unruptured aneurysm are under a higher level of anxiety and depression than the norm. This can negatively affect cognitive functions such as visual memory, motor speed, verbal information processing, and executive function. The authors also reported that these negative effects were improved after surgical clipping.

Postoperative pain and the effect of total anesthesia can also be contributing factors (described later). In addition to these factors, intraoperative hypoperfusion or hypoxia caused by temporary clipping, brain retraction, vasoconstriction after surgery, neurotoxicity of blood that flowed into the cistern,¹⁵⁾ debilitation after surgery,¹⁶⁾ and minor contusion represent possible causes of deterioration.

The subgroup analysis showed that the negative effect of the surgical procedure on cognitive function was significant in older patients as well as those with a large aneurysm or an anterior communicating artery aneurysm or who underwent long operations. A multivariate analysis comparing patients who exhibited a reduction in TMT-A score of more than 2 SD of the mean with those who did not exhibit a reduction revealed the size of the aneurysm as a possible independent contributor to cognitive

impairment. Though there were limitations related to sample size, particularly in the subgroup and multivariate analyses, these results can be considered suggestive and are in accord with a prior report.¹⁾

Either the interhemispheric or pterional approaches can be used to clip anterior communicating artery aneurysms. Both techniques require the retraction of the frontal lobe to some extent, but the former is more invasive to the frontal lobe. Therefore, a significant impairment of frontal lobe function in the group that underwent the interhemispheric approach is reasonable.

There are several possible confounding factors related to the early postoperative neuropsychological evaluation. First, approximately 1 week after surgery, patients may still be experiencing temporal lobe swelling and changes in cerebrospinal fluid that can cause pain, a well-characterized confounder. Postoperative pain was treated with nonsteroidal anti-inflammatory drugs (NSAIDs) during this study, but the pain scale was not recorded at the time of neuropsychological evaluation. Neuropsychological deterioration caused by such reversible factors may improve eventually. We decided to perform the neuropsychological tests at such an early stage after surgery because any negative postoperative changes should be recognized as soon as possible so as to begin appropriate interventions such as rehabilitation and maximize their effects. Second, the residual effects of general anesthesia can confound analyses at such an early postoperative time point, particularly in older patients. Third, there might be a practice effect with such a short interval between rounds of testing. To clarify the effects of these possible confounders, we present the results of a survey of perioperative neuropsychological changes (assessed by the same design as the current study) in 56 consecutive patients who underwent microvascular decompression (MVD) surgery for hemifacial spasm (HFS) as a control (Table 5). The surgical procedures

Table 5 Perioperative neuropsychological test score of microvascular decompression for hemifacial spasm

Test	Score: mean \pm SD (95% CI)		P value	No. of cases
	Pre	Post		
Overall				56
HDS-R	28.8 \pm 0.2 (28.4–29.2)	29.1 \pm 0.2 (28.7–29.5)	0.20	
MMSE	28.6 \pm 0.3 (28.0–29.1)	28.8 \pm 0.3 (28.4–29.3)	0.19	
FAB	16.7 \pm 0.2 (16.3–17.0)	17.1 \pm 0.3 (16.5–17.7)	0.07	
TMT-A	100.0 \pm 4.3 (91.6–108.5)	94.1 \pm 3.8 (86.4–101.7)	0.17	
TMT-B	131.0 \pm 6.3 (118.5–143.5)	132.1 \pm 7.5 (117.3–147.0)	0.85	

HDS-R: Revised Hasegawa Dementia Scale, MMSE: Mini-Mental State Examination, FAB: Frontal Assessment Battery, TMT: Trail Making Test, SD: standard deviation, CI: confidence interval.

were performed under total anesthesia, and the operative duration was 193 ± 38 min. The mean age of the patients was 52.8 ± 8.8 years. Twenty-four were male and 32 were female. Preoperative neuropsychological evaluations were completed within 1 week prior to surgery, and postoperative evaluations were completed within 6.0 ± 1.7 (2–10) days. Neither significant deterioration of the TMT-A score nor improvement of the FAB or RCPM scores was observed among the cases of MVD for HFS. Even though the patient's characteristics were different between the two studies, this comparison suggests that the perioperative neuropsychological changes observed in the current study were specific consequences of the surgical procedure for UIA rather than an effect of these confounding factors.

In the present study, we showed that neuropsychological function changes in the early period after surgery, though these changes seem to be influenced by many factors. Considering the functions of each neuropsychological test and our results, we believe that surgical clipping for a UIA may impair the visual search function but improve visuoperceptual function, analogical function, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and cognitive flexibility. Some invasions that are not evident in radiological examinations or the craniotomy itself may cause damage to the brain, but the distinct etiologies of the neuropsychological changes cannot be distinguished on the basis of our study alone.

In the process of choosing a surgical indication, mortality and the risk of evident neurological deficits and physiological complications are compared with the benefit of the procedure. With technical advances in microsurgical and monitoring techniques, surgical outcomes have been improving for years, but their effects on cognitive function have received far less attention. Although the deterioration of cognitive function after the surgical procedure for a UIA was mild and acceptable, it is important to note that the procedure does affect cognitive function. We should consider its negative effects in older patients as well as in patients with large aneurysms, anterior communicating artery aneurysms and those who underwent long operations.

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Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials or devices used in the article. All authors who are members of the Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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