Microembolism after endovascular coiling of unruptured cerebral aneurysms: incidence and risk factors

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OBJECTIVE The incidence and risk factors of microembolic lesions on MR diffusion-weighted imaging (DWI) were analyzed after the endovascular coiling of unruptured intracranial aneurysms (UIAs).

METHODS Data obtained from 271 consecutive patients (70 men and 201 women; median age 57 years; range 23–79 years) who presented with UIA for coil embolization between July 2011 and June 2013 were analyzed. Two independent reviewers examined the DWI and apparent diffusion coefficient maps obtained the following day for the presence of restrictive diffusion spots and counted the number of spots. Multivariate analysis was then performed to identify independent risk factors for developing microembolism following the coiling of an aneurysm.

RESULTS Microembolic lesions were noted in 101 of 271 patients (37.3%). The results of the multivariate analysis showed that the following factors significantly influenced the risk for microembolism: age, diabetes, previous history of ischemic stroke, high-signal FLAIR lesions in the white matter, multiple aneurysms, and the insertion of an Enterprise stent (all ORs > 1.0 and all p values < 0.05). Previously known risk factors such as prolonged procedure duration, aneurysm size, and decreased antiplatelet function did not show any significant influence.

CONCLUSIONS The incidence of microembolism after endovascular coiling of UIA was not low. Lesions occurred more frequently in patients with vascular status associated with old age, diabetes, and previous stroke. Aneurysm multiplicity and the type of stent used for treatment also influenced lesion occurrence.

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KEY WORDS unruptured cerebral aneurysm; endovascular coiling; diffusion-weighted imaging; microembolism; vascular disorders

MICROEMBOLIC lesions appearing as high signal intensity (HSI) spots on diffusion-weighted imaging (DWI) and restrictive diffusions on the corresponding apparent diffusion coefficient (ADC) maps are often seen following a variety neurovascular procedures. Reportedly, 10% to 76.5% of DWI studies obtained after endovascular coiling of unruptured intracranial aneurysms (UIAs) show such microembolic spots (Fig. 1).^{2–4,8,9,15,22,24–26} Most patients who show HSI spots are asymptomatic, and the clinical significance of such spots remains controversial. However, the HSI spots reflect the presence of damaged tissue,^{5,7,12,15} and their associated potential risks cannot be ignored.

This study was conducted to analyze the current incidence of postprocedural DWI HSI lesions at our institution and to explore the possible risk factors for microembolic

lesions visible as HSI spots on DWI after endovascular coiling of UIAs.

Methods

Patient Population

Our local institutional review board approved this retrospective study, and the requirement for patient informed consent for data collection and analyses was waived. We used our neurointerventional database to identify a total of 293 consecutive patients who had presented with a UIA for endovascular treatment between July 2011 and June 2013. Among 293 patients, we excluded 13 patients in whom the aneurysm was treated with parent artery trapping without endosaccular coiling and 2 other patients in whom endovascular management was unsuccessful due to selection

ABBREVIATIONS ACT = activated clotting time; ADC = apparent diffusion coefficient; BMI = body mass index; DM = diabetes mellitus; DWI = diffusion-weighted imaging; HSI = high signal intensity; PRU = P2Y12 reaction unit; UIA = unruptured intracranial aneurysm.

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FIG. 1. Coil embolization was attempted in a 71-year-old female patient who presented with an unruptured aneurysm originating from the anterior communicating artery. **A:** Part of the coil loops herniated into the parent artery after detachment of the finishing coil. **B:** Three-dimensional angiogram obtained after the placement of an Enterprise stent, showing good patency of the parent artery. **C and D:** DWI images obtained the following day show multiple HSI spots along the borderzone of both internal carotid arteries. Figure is available in color online only.

failure. No cases were treated using flow diversion in this study since the treatment is not currently available in Korea. The remaining 278 cases were treated with endovascular coiling. DWI and ADC results were not available for 7 patients who refused such examinations or were contraindicated for MRI. It should be noted that none of these 7 patients were symptomatic postoperatively. Finally, postprocedural DWI and ADC results were available for 271 patients.

Embolization and Postprocedural Care

All patients received dual antiplatelet medications (100 mg aspirin 4 times per day; 75 mg clopidogrel 4 times per day) for at least 5 days (preferably ~ 10 days) prior to the procedure without a loading dose. The P2Y₁₂ inhibition assay (VerifyNow P2Y₁₂ Assay, Accumetrics) was performed on each patient at admission. When the test result showed a P2Y₁₂ reaction unit (PRU) value ≥ 240 , the patient received a 200-mg loading dose of cilostazol (Pletal, Otsuka Pharmaceutical Co.) followed by 50 mg of cilostazol twice per day in addition to dual antiplatelet medications. Following the administration of general anesthesia, systemic heparinization was achieved with a target activated clotting time (ACT) of 200 to 250 seconds or 2 to 2.5 $\times$ baseline; thereafter, heparin was administered at a dose of 1000 units/hour.

After placing a microcatheter, embolization coils were inserted into the aneurysm sac. A variety of different coils, including Trufill Orbit coils (Codman), Axiom coils (Covidien), HydroSoft coils (MicroVention), and Target coils (Stryker) were used to fill the sac. Although the coils were selected at the surgeon's discretion, various coils were used in combination to treat an aneurysm. A variety of different assistive methods (multiple microcatheter technique, balloon-assisted technique, stent-assisted technique, and combined technique) were applied. The balloon-assisted technique was performed using HyperForm or HyperGlide balloons (MicroVention). Two types

of stents, a Neuroform stent (Stryker) and an Enterprise stent (Codman), were used based on the patient's anatomy or the individual operator's preference.

After completing the procedure, each patient was transferred to the neurosurgical intensive care unit without the reversal of systemic heparinization. In uneventful cases, the patient was observed for 24 hours in the neurosurgical intensive care unit and for another 24 hours in the general ward. All patients were continued on a regimen of dual (or triple) antiplatelet medications prior to discharge. Upon discharge, patients who did not require stent insertion were maintained on a 4-week course of aspirin monotherapy (100 mg daily). If a stent was implanted, the patient was placed on a 2-month course of dual antiplatelet agents, followed by aspirin monotherapy for at least 4 months. No patients were put on a regimen of triple antiplatelet regimen after discharge.

Postprocedure DWI and Corresponding ADC Analysis

To establish a baseline for follow-up imaging, we routinely obtained time-of-flight MR angiography together with DWI and ADC on postprocedural Day 1, usually about 24 hours after the procedure. DWIs were obtained using a 3.0-T Achieva MRI system (Philips Medical Systems). A single-shot spin-echo echo planar imaging technique was used with a b-value of 1000 sec/mm² with the following imaging parameters: echo time 56 msec, repetition time 3000 msec, field of view 250 mm $\times$ 250 mm, matrix size 128 $\times$ 128, slice thickness 5 mm with a gap of 2 mm, number of slices 20, number of averages 1. Parallel imaging was not applied. The ADC map was generated automatically from the acquisition console.

Two neuroradiologists (D.Y.K. and C.G.C.) who had 2 and 21 years of experience, respectively, reviewed all images independently. Each reviewer was independently asked to identify any HSI spots. Any lesion that could not be explained as an artifact, normal cortical signal, or white matter bundles was regarded as positive. While

there were no size criteria for HSI spots, lesions with a maximum diameter > 10 mm were regarded as an obvious infarct lesion and were also included when counting the total number of microembolic lesions. Cases showing any HSI spot in the brain were regarded as DWI positive. The DWI positivity rates were calculated for both target and nontarget areas. The target area was defined as the entire arterial territory visualized on selective angiography of the vessel where the guiding catheter was placed.

The kappa statistic was used to assess interobserver agreement for counting HSI spots. When a discrepancy existed in the number of spots counted in a particular lesion, agreement on the final count was reached by discussion between the 2 readers. The various levels of reader agreement were defined as follows: a kappa value ≤ 0.2 indicated poor agreement, 0.2–0.4 indicated fair agreement, 0.4–0.6 indicated moderate agreement, 0.6–0.8 indicated good agreement, and 0.8–1.0 indicated excellent agreement (SPSS version 11).

Data Collection

Data in the medical records were collected for the following parameters: demographics (age and sex), body mass index (BMI), smoking history (current or ex-smoker), and alcohol use. Data collected from the medical histories included a diagnosis of diabetes mellitus (DM; the patient was being managed for blood sugar levels, or showed a recent fasting blood glucose level > 125 mg/dl at > 2 times on admission); hypertension or hyperlipidemia (the patient was taking statins or had a total cholesterol level > 240 mg/dl on admission); or a history of coronary heart disease, stroke, or a cerebral catheter angiography conducted within the previous 7 days.

FLAIR images obtained within 6 months prior to the procedure were available for 210 of 271 patients (77.5%). For 61 patients who did not have recent FLAIR results available, recent T2-weighted images or B₀ images of the DWI obtained on postprocedural Day 1 were reviewed. Periventricular white matter HSI lesions were evaluated using the grade system proposed by Fazekas et al.⁶ Pre-existing white matter lesions could be differentiated from the HSI spots caused by a recent microembolism. The grading system had 4 grades that ranged from 0 to 3, and Grades 3 and 4 were regarded as significant white matter lesions.⁶

Angiography data were collected to determine the number of aneurysms, location of an aneurysm (anterior or posterior circulation), and maximum diameter of the aneurysm sac. In the case of multiple aneurysms, the largest aneurysm was designated as the index aneurysm. Parent artery morphology, including the presence of atherosclerotic luminal irregularities, was also analyzed. All imaging analyses other than the DWI and ADC results were done by a neuroradiologist (D.H.L.) who has 14 years of experience.

Procedural data were collected by reviewing the procedural reports. Such data included the results of the VerifyNow Assay, the ACT value, the total number of coils used, any use of an assistive technique, and the duration of the procedure starting from the first-run angiography to the completion of the final angiography. We included

information on the types and number of stents used. We also obtained the duration of fluoroscopic exposure from the dose chart.

Intraprocedural complications such as a coil loop herniation (herniation of any part of the coil regardless of flow disturbance), thromboembolism (including thrombus formation at the interface between the coil margin and parent artery), and premature aneurysmal rupture were also analyzed. The patient's mean arterial pressure during the procedure was calculated using information from the anesthesia records. Additionally, the symptomatic DWI positivity rates were also calculated. Any neurological change was considered symptomatic regardless of whether the symptom or sign was transient or persistent.

Statistical Analysis

Categorical variables are presented as numbers and percentages and were compared using the chi-square test or Fisher exact test. Continuous variables are expressed as the mean $\pm$ standard deviation (SD) and were compared using the unpaired Student t-test or Mann-Whitney U-test, as appropriate. Logistic regressions were used to estimate the independent contributions of variables to the occurrence of any HSI spot. Variables with $p \leq 0.05$ in the univariate analyses and known to be predisposing factors according to previous studies were candidates for analysis using a multivariable logistic regression model. A backward elimination process ($p \leq 0.05$ was required to retain the variable) was used to develop the final multivariable models. A 2-tailed p value < 0.05 was considered statistically significant. All statistical data were analyzed using SAS version 9.1 (SAS Institute).

Results

Characteristics of the Patients

The 271 patients had a mean age of 57.2 years (range 23–79 years) and 74.9% were women, which reflects the female predominance of cerebral aneurysms. Additional patient characteristics, as well as procedure-related variables, are summarized in Table 1. Stent-assisted coiling was conducted in 105 patients (38.7%), 9 of whom received multiple stents. Three patients received both Neuroform and Enterprise stents for the same aneurysm due to various reasons.

Procedural Outcomes

Intraprocedural rupture of an aneurysm occurred in 4 patients (1.5%). Among these patients, 1 experienced a permanent neurological deficit, another developed hydrocephalus that did not require a shunt, while the other 2 patients did not suffer clinical consequences.

There were 5 (1.9%) intraprocedural thrombotic or thromboembolic events, 2 of which were associated with coil loop herniation that compromised the origin of the branching vessel. All 5 of these cases were successfully managed by systemic tirofiban, and none of these patients were symptomatic following the procedure. An intravenous loading dose of tirofiban (Aggrastat, Merck) (0.4 μ g/kg/min for 30 minutes) was administered. The use

TABLE 1. Demographic and clinical characteristics of the 271 enrolled patients

Characteristic	Value
Mean age (yrs)	
Mean	57.2 ± 10.3
Range	23–79
Male/female	68 (25.1):203 (74.9)
BMI >25	124 (45.8)
Alcohol user	84 (31.0)
Current or exsmoker	65 (24.0)
DM or hyperglycemia (>125 mg/dl)	51 (18.8)
Hypertension	125 (46.1)
Hyperlipidemia or total cholesterol (>240 mg/dl)	90 (33.2)
Previous stroke history	23 (8.5)
Previous coronary artery disease	15 (5.5)
History of recent angiographic study w/in 7 days	37 (13.7)
White matter lesion (Fazeka Grade 2 or 3)	27 (10.0)
Multiple aneurysm	37 (13.7)
Location of aneurysm	
Anterior circulation	226 (83.4)
Posterior circulation	45 (16.6)
Mean maximum diameter of aneurysm (mm)	5.76 ± 2.99
Atherosclerotic luminal irregularities of parent artery	20 (7.4)
PRU (>241)	123 (45.9)
Activated clotting time (<249 sec)	148 (54.6)
Mean total no. of coils used	5.39 ± 3.24
Stent-assisted†	
Neuroform stent	85 (31.4)
Enterprise stent	23 (8.5)
Multiple microcatheter technique	59 (21.8)
Balloon-assisted technique	16 (5.9)
Mean duration of fluoroscopy (mins)	50.1 ± 28.1
Mean procedure duration (mins)	71.0 ± 38.0
Any coil loop herniation	29 (10.7)
Intraprocedural thrombosis or thromboembolism	5 (1.9)
Intraprocedural rupture	4 (1.5)
Mean arterial pressure during anesthesia (mm Hg)	76.3 ± 38.0

* Data are presented as the number of patients (%) unless noted otherwise. Mean data are presented as the mean ± SD.

† Three patients received both Neuroform and Enterprise stents.

of maintenance dosing was reserved for refractory cases. Among these, a Neuroform stent was used to bail out flow disturbance in 1 case. On the postprocedure DWI studies of these patients, 1 patient showed focal asymptomatic cortical infarction in the involved territory. Three other patients showed several microembolic spots, and 1 patient showed no DWI abnormality.

The results of the follow-up visits after discharge showed that 3 patients were symptomatic due to delayed thromboembolism. Transient hemiparesis due to middle cerebral artery territory infarction was observed in 2 pa-

tients treated with simple coiling after 5 days and 4 weeks while receiving aspirin medication, and occipital lobe infarction was detected in the other patient with a basilar tip aneurysm who was treated with stent-assisted embolization after 40 days while receiving dual antiplatelet medication. All 3 patients showed no neurological symptoms at the last follow-up.

DWI Positivity Rate

Our analysis showed good interobserver agreement for counting HSI spots ($\kappa = 0.707$). A total of 101 patients (37.3%) showed at least 1 HSI spot, and 8 patients showed a lesion with a diameter > 1 cm. Among the 101 DWI-positive patients, only 3 (3.0%) were symptomatic. Lateral medullary infarction occurred in 1 patient in whom distal vertebral artery stenting was performed simultaneously with coiling of the associated aneurysm. The other 2 patients displayed transient unilateral facial weakness due to right pontine microembolic lesions and transient ophthalmoplegia due to cerebellar and brainstem microembolic lesions, respectively. The remaining patients with cortical or subcortical patch lesions did not display any neurological deficit. The distribution of HSI spots is summarized in Table 2. Nontarget territory spots were noted in 15 patients (5.5%).

Results of the Uni- and Multivariate Analyses

The univariate analyses showed that there were statistically significant differences between the DWI-positive and DWI-negative groups in terms of age, DM, hypertension, previous history of stroke, significant white matter lesions on MRI, atherosclerotic changes in the parent artery, use of an Enterprise stent during the assistive procedure, duration of fluoroscopy, and duration of the procedure. The size of an aneurysm, incidence of thromboembolic complications, and prolonged PRU values did not show statistically significant differences (Table 3).

A subsequent multivariate analysis showed several significant risk factors for HSI spots (Table 4), which included age, DM, a previous history of stroke, presence of white matter lesions on MRI, multiple aneurysms, and the use of the Enterprise stent for assistive techniques. The DWI-positive and DWI-negative groups showed no significant difference regarding the duration of the procedure.

Discussion

HSI spots found after the endovascular coiling of unruptured cerebral aneurysms have been suspected to be microembolic infarcts probably related to tiny thrombi, fragmented atherosclerotic plaques, air bubbles, or hydrophilic coating materials liberated or introduced during catheter insertion and/or the injection of contrast media or flushing saline.^{19,23}

Over 70% of our cohort showed less than 5 HSI spots, and 97% of our DWI-positive patients were asymptomatic. It could be assumed that seeking to identify such imaging abnormalities would provide only minor clinical benefits compared with the use of less invasive endovascular treatments. However, the clinical and long-term consequences of harboring a postembolization microembolism remain

TABLE 2. Distribution of microembolic lesions

No. of Lesions	No. of Patients (%)
0	170 (62.7)
1	41 (15.1)
2	20 (7.4)
3	4 (1.5)
4	6 (2.2)
5	0 (0)
6–10	19 (7.0)
>10	11 (4.1)

controversial. In a previous study, a higher number of microemboli detected as DWI-positive spots may have been a surrogate marker for symptomatic ischemic complication.¹⁵ Microembolic silent brain ischemia is also a contributor to cognitive decline and dementia.^{5,7} In addition, these microembolic lesions after interventional procedures negatively impact cognitive functions.²¹ Because there is no unanimous opinion regarding the risks associated with harboring such lesions, it might be beneficial to reduce their numbers as much as possible.

We found multiple variables that were significant on univariate analysis. Eventually, we found several variables associated with the occurrence of DWI-positive lesions on the subsequent multivariate analysis. There are several reports regarding the risk of developing HSI lesions following the endovascular treatment of unruptured aneurysms. Some are in line with previous reports and some are not. These studies reported that age was the only significant risk factor for developing multiple HSI lesions.^{3,15} We can confirm that association in our study also. Other patient characteristics such as sex and BMI did not show any influence.

In contrast to some previous reports,^{13,26} we did not observe any relationship between microembolism occurrence and the maximum diameter of an aneurysm. However, our findings were in agreement with several other reports that also failed to show that relationship.^{3,8,15,25} Our univariate analysis suggested a positive relationship between microembolism occurrence and procedure duration; however, this relationship was not confirmed in the subsequent multivariate analysis. Procedure duration or fluoroscopy duration might be affected by the complexity of the aneurysm or related assistive procedure. If we did not include other variables such as the assistive techniques, the result could have differed, as was suggested by another report.⁹

The use of antithrombotics such as antiplatelet and anticoagulant drugs is obviously a very important issue. Heparin use has previously been suggested as an important variable.^{1,20} Matsushige et al. studied the use of antiplatelet drugs for premedication and reported the lower occurrence of microembolism in patients treated with multiple antiplatelets.²² The DWI positivity rate in our series (37.3%) was slightly lower than the overall rate (49.7%) calculated by previous studies, which showed rates ranging from 10% to 76.5% (most being ~ 50%).^{2–4,8,9,15,22,24–26} One possible reason for the lower rate in our study may

TABLE 3. Demographic, clinical, and procedural characteristics of all patients and the differences between DWI-positive and DWI-negative patients*

Variable	DWI Negative (n = 170)	DWI Positive (n = 101)	p Value
Mean age, yrs	55.4 ± 10.6	60.3 ± 9.1	<0.001
Male	41 (24.1)	27 (26.7)	0.631
BMI (>25)	73 (42.9)	51 (50.5)	0.228
DM	22 (12.9)	29 (28.7)	0.002
Hypertension	68 (40.0)	57 (56.4)	0.009
Hyperlipidemia	55 (32.4)	35 (34.7)	0.697
Previous stroke history	5 (2.9)	18 (17.8)	0.000
White matter lesions	8 (4.7)	19 (18.8)	0.008
Recent angiographic study w/in 7 days	20 (11.8)	17 (16.8)	0.242
Multiple aneurysms	15 (8.8)	22 (21.8)	0.004
Location of aneurysms			0.351
Anterior circulation	139 (81.8)	87 (86.1)	
Posterior circulation	31 (18.2)	14 (13.9)	
Mean diameter of the aneurysms, mm	5.57 ± 2.73	6.08 ± 3.38	0.180
Atherosclerotic luminal irregularities	8 (4.7)	12 (11.9)	0.035
PRU (>241)	71 (42.3)	52 (52.0%)	0.123
Activated clotting time (<249 sec)	95 (55.9)	53 (52.5)	0.586
Mean total no. of coils used	5.18 ± 3.13	5.74 ± 3.42	0.174
Stent assisted†			
Neuroform stent	53 (31.2)	32 (31.7)	0.931
Enterprise stent	4 (2.4)	19 (18.9%)	<0.001
Multiple microcatheter technique	31 (18.2)	28 (27.7)	0.069
Balloon-assisted technique	7 (4.1)	9 (8.9)	0.114
Mean duration of fluoroscopy, mins (mean ± SD)	45.4 ± 23.6	58.1 ± 33.2	0.001
Mean procedure duration, mins	65.0 ± 34.0	82.0 ± 41.0	<0.001
Any coil loop herniation	18 (10.6)	11 (10.9)	0.938
Thromboembolism	1 (0.6)	4 (4.0)	0.084
Intraprocedural rupture	2 (1.2)	2 (2.0)	0.600
Mean arterial pressure, mm Hg	76.2 ± 5.7	76.5 ± 5.0	0.645

* Data are presented as the number of patients (%) unless otherwise noted.

Mean values are presented as the mean ± SD.

† Three patients received both Neuroform and Enterprise stents.

have been the strict anticoagulation and antiplatelet regimen that was used. Our patients received premedication with 2 antiplatelet drugs for > 5 days (preferably ~ 10 days) prior to their procedure, regardless of whether the use of a stent was anticipated.^{17,18} The PRU value did not correlate with the occurrence of DWI positivity because we added cilostazol if the pretreatment clopidogrel function test result was suboptimal. The need for antiplatelet func-

TABLE 4. Multivariate analysis of the factors associated with microembolism

Variable	p Value	Adjusted OR	95% CI	
			Lower	Upper
Age (per year)	0.010	1.044	1.011	1.079
DM	0.002	3.209	1.542	6.760
Previous stroke history	0.044	3.580	1.034	12.396
White matter lesion (Fazeka Grade 2–3)	0.001	5.481	1.926	15.595
Multiple aneurysms	0.018	3.075	1.208	7.825
Enterprise stent	<0.001	10.72	2.903	39.605
Multiple microcatheter technique	0.076	1.900	0.934	3.864
Duration of fluoroscopy (per minute)	0.095	1.012	0.998	1.026
Any coil loop herniation	0.072	0.895	0.793	1.010

tion monitoring and the actual benefits of using a multiple-antiplatelet regimen require further evaluation.

We found that atherosclerotic vascular risk factors (advanced age, DM, history of previous stroke) and an indicator of small vessel disease on imaging (FLAIR signal abnormality in the white matter) were significantly related to the occurrence of DWI-positive lesions. This can be explained by the impaired clearance of microemboli in patients with high-risk vascular status. High baseline atherosclerosis and vascular tortuosity in older patients may increase microemboli.¹⁵ It is also possible that the occurrence of microembolic infarcts in such patients might result in more serious clinical consequences due to a pre-existing white matter lesion burden.⁵

Because we used various detachable coils in combination for treating aneurysms, we were unable to analyze any possible influence of coil type on the occurrence of a microembolism. Kim et al. reported the possible influence of coil type on the occurrence of microembolism.¹⁶ In addition to that report, there is another report that suggests the possibility that a certain coil could be a significant source of introducing air bubbles.¹⁹

Our multivariate analysis shows that most assistive techniques or complex procedures (longer fluoroscopic times) did not have any statistically significant influence on the occurrence of microembolism. However, the use of an Enterprise stent was associated with an adjusted odds ratio > 10, while the use of a Neuroform stent was not an influencing factor. Other researchers have also suggested the possible influence of stent type.^{10,11} They hypothesized that poor apposition of the stent mesh to the arterial wall, or shedding of stent coating materials (Parylene), could be the cause of the microemboli that frequently occur in cases treated with Enterprise-stent assistance. However, since the majority of stent-assisted procedures were performed using the Neuroform stent in our series (79%), it is too early to reach a conclusion.

This study has several limitations that should be mentioned. First, even though 2 experienced neuroradiologists reviewed the postprocedural DWI studies and ADC maps,

some DWI abnormalities were difficult to characterize and a perfect consensus was not always reached. We believe that this is the main reason that the interobserver k value did not reach a level > 0.8. Second, due to the retrospective nature of the data collection, we experienced some difficulty in defining certain clinical variables such as DM, hypertension, and hyperlipidemia. The validity of this information was only supported by the patient's personal statement and laboratory data. To minimize the possible underestimation of unrecognized conditions, we applied arbitrary criteria that were based on routine laboratory test results in addition to the history-based information. This could have resulted in data bias. Third, to evaluate symptomatic lesions, we did not perform neurocognitive tests. Kang et al.¹⁴ reported that the neuropsychological evaluation of patients with UIA who underwent coil embolization demonstrated cognitive deficits in the immediate period; however, these results recovered or improved from baseline cognitive function after 4 weeks. In addition, they found no statistically significant relationship between the presence and number of clinically silent ischemic lesions on DWI and cognitive changes after the procedure.

Conclusions

Although most of the lesions were asymptomatic (97%), the incidence of microembolism after coil embolization for UIA is not low (37.3%). Microembolism after coiling occurred more frequently in patients with atherosclerotic risk factors such as advanced age, DM, or a previous history of stroke. The risk was also higher in patients with evidence of white matter lesions on MR imaging. The occurrence of microembolism was also influenced by the multiplicity of aneurysms treated at the same session and the type of stent used for the stent-assisted procedure.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Lee, Park. Acquisition of data: Lee, Park, JK Kim, Ahn, DY Kim, Choi. Analysis and interpretation of data: Lee, Park, JK Kim, Ahn, Kwun, DY Kim. Drafting the article: Lee, Park. Critically revising the article: Lee, Park, Ahn, Kwun, Choi. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Lee. Statistical analysis: Lee, Park, Ahn, DY Kim. Administrative/technical/material support: Lee. Study supervision: Lee, Kwun.

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