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CLINICAL ARTICLE

The impact of initial vascular morphology on outcomes in patients with intracranial vertebral artery dissection presenting with isolated headache

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OBJECTIVE The prognosis of isolated headache intracranial vertebral artery dissection (iVAD) without subarachnoid hemorrhage (SAH) or stroke is unknown. The authors of this study aimed to evaluate isolated headache iVAD prognosis.

METHODS This is a single-center retrospective study of consecutive patients who presented with headache as their main complaint and underwent MRI between November 2016 and August 2022; those with acute isolated headache iVAD who were followed up for vascular morphological stability were eligible for study inclusion. The patients were divided into three groups based on the vascular morphology at initial diagnosis: aneurysm dilatation without stenosis (group 1), aneurysm dilatation with stenosis (group 2), and no aneurysm dilatation (group 3). Prognosis, time to radiological stability, and final vascular morphology were compared among the groups.

RESULTS One hundred five patients with isolated headache iVAD were included in the study. During a median follow-up of 478 (IQR 143–1094) days, none of the patients developed SAH or stroke, but 3/41 (7%) patients in group 1 underwent endovascular intervention for aneurysm enlargement. Patients in group 1 required significantly more long-term follow-up for morphological stability ($p = 0.013$), primarily due to aneurysm enlargement ($p < 0.001$), and were more likely to require surgical intervention ($p = 0.043$) than those in the other two groups. Residual aneurysm risk was significantly associated with initial vascular morphology in group 1 (OR 7.28, 95% CI 2.30–23.1, $p < 0.001$).

CONCLUSIONS Most patients with isolated headache iVAD had a favorable prognosis. However, patients with aneurysm dilatation without stenosis required the most careful follow-up, as this group had the highest aneurysm enlargement risk from early disease onset through the chronic phase. In such cases, patients may require surgical intervention to prevent critical conditions.

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KEYWORDS intracranial vertebral artery dissection; headache; primary care; aneurysm; prognosis; vascular disorders

Intracranial vertebral artery dissection (iVAD) is an essential etiology of subarachnoid hemorrhage (SAH) and brainstem infarction in young to middle-aged patients.[1] Rare iVAD manifestations include isolated headaches or brainstem compression symptoms.[2] However, the detection of patients with isolated headache iVAD has increased with greater iVAD familiarity and imaging advances.[3,4]

Clinical research on iVAD to date has focused primarily on patients with SAH, and the clinical course and treatment strategy are generally well established.[5–12] Ischemic iVADs have also been widely studied, with a focus on determining the impact of antithrombotic medications on prognosis and establishing treatment strategies accordingly.[1,2,13] However, management strategies and the prognosis of headache-onset iVAD still need to be established.

ABBREVIATIONS AICA = anterior inferior cerebellar artery; BPAS = basi-parallel anatomical scanning; iVAD = intracranial VAD; PICA = posterior inferior cerebellar artery; SAH = subarachnoid hemorrhage; VAD = vertebral artery dissection.

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Isolated headache iVAD has been reported to have a generally good prognosis in small case series.[14,15] However, some patients develop cerebral infarction or SAH during the disease.[15] Therefore, the iVAD radiological course and prognosis urgently need to be clarified.

This study aimed to evaluate isolated headache iVAD prognosis and identify the risk factors for patients requiring aggressive treatment before SAH or stroke. A total of 105 consecutive isolated headache iVAD cases followed up using MRI were retrospectively analyzed for clinical prognosis and vascular morphological changes.

Methods

Standard Protocol Approvals, Enrollment, and Patient Consent

The institutional review board of our hospital approved this retrospective study, and eligible patients were allowed to opt out.

Patients

In total, 11,650 patients had presented with headache as their main complaint and underwent MRI at a single neurosurgical clinic between November 2016 and August 2022. From among this group, we sought those patients who had been diagnosed with cerebrovascular artery dissection using MRI. Isolated headache iVAD cases that met all selection criteria and none of the exclusion criteria were included in the analysis.

The inclusion criteria were an identifiable onset date for headache due to iVAD, based on the clinical course (the day of headache onset was counted as day 1); a diagnosis of acute iVAD using 1.5-T MRI; and an ability to be followed up until the morphological changes in the lesion vessel appeared stabilized on MRI.

Cerebral artery dissection diagnosis using MRI was conducted according to the Spontaneous Cervicocephalic Arterial Dissections Study Japan (SCADS-Japan) imaging criteria,[16] which were used in a nationwide survey in Japan and are defined as follows: diagnosis by time-of-flight MRA or fat-suppressed T2-weighted imaging with a double lumen or intimal flap; MRA with the pearl-and-string sign or fusiform aneurysm; and MRA showing only a string sign or tapered occlusion. In this latter case, basiparallel anatomical scanning (BPAS) and fat-suppressed T2-weighted imaging were performed to differentiate such findings from hypoplasia. Acute onset was defined as hyperintense intramural hematoma with high signal intensity on fat-suppressed T1-weighted imaging with black blood, morphological changes of the lesion vessel over time, and progressive development of lesion-related SAH symptoms or stroke. A double lumen, an intimal flap, and dynamic changes in vessel morphology over time were key criteria for differentiating iVAD from nonpathological fusiform dilatation, which is characterized by a uniform enlargement of the artery without these dissection-specific features.

Patients whose disease had been possibly caused by trauma, those whose clinical course and imaging findings did not exclude old lesions, and those with a diagnosis of SAH or cerebral infarction associated with vertebral artery dissection (VAD) at the initial examination were excluded from the study.

Clinical and Radiological Evaluation

The following information was collected from the medical records: age, sex, medical history (hypertension, diabetes, and current smoking), and time from disease onset to the first visit. Next, two board-certified neurosurgeons (A.O. and M.H.) evaluated the radiological findings, and disagreements were resolved by consensus. These findings included the initial and final morphology, double lumen, intramural hematoma, and relationship with the posterior inferior cerebellar artery (PICA). The anterior inferior cerebellar artery (AICA)–PICA, contralateral PICA, and extracranial PICA were categorized and referred to as "non-PICA." The initial vascular morphology was classified into three groups based on aneurysm dilatation and stenosis: aneurysm dilatation without stenosis (group 1), aneurysm dilatation with stenosis (group 2), and no aneurysm dilatation (group 3). Group 1 consisted primarily of fusiform aneurysms, whereas group 2 included pearl-and-string changes. Group 3 included steno-occlusive lesions only. Stenotic lesion length, the borderline between groups 1 and 2, was defined as stenosis > 50% in the long-axis direction of the affected area (Fig. 1). The size of the aneurysm was measured as the maximum transverse diameter of the vessel at the bulging site. Angiographic assessment was performed for all treated patients to evaluate the vascular morphology and treatment outcomes; this included DSA to ensure accurate visualization of the lesion and to guide the intervention strategy. Furthermore, posttreatment angiographic follow-up was conducted to monitor any recurrence or complications.

Treatment Strategy and Clinical Follow-Up

All patients were instructed to lower their blood pressure, stop smoking, and limit their neck rotation. Antiplatelet agents were generally not used but were considered if the patient was at high risk for cerebral infarction, a rapidly progressive narrowing, or artery occlusion. The basic iVAD follow-up policy is MRI at approximately 2 weeks, 2 months, and 6 months after the initial imaging. Follow-up was terminated when no imaging changes had been observed on two consecutive occasions, indicating imaging stability. Aneurysms ≤ 5 mm with no enlargement tendency were not subject to regular imaging follow-up but were followed up on a case-by-case basis if there were findings requiring follow-up other than per the patient's request. Aneurysms > 5 mm were followed up every 6–12 months, depending on the degree of aneurysm involvement. Patients were referred to a general hospital for further evaluation and surgical decision if they experienced a stroke or SAH, if their aneurysm enlarged to approximately 10 mm in size, or if they had an aneurysm with a bleb. Regarding final vascular morphology, patients were categorized into one of the following imaging categories based on the following definitions: 1) aneurysm, recognizable residual aneurysm formation on MRA, fat-suppressed T2-weighted imaging, or BPAS; 2) occlusion, occlusion or near occlusion of the affected vessel with no further changes observed; 3) im-

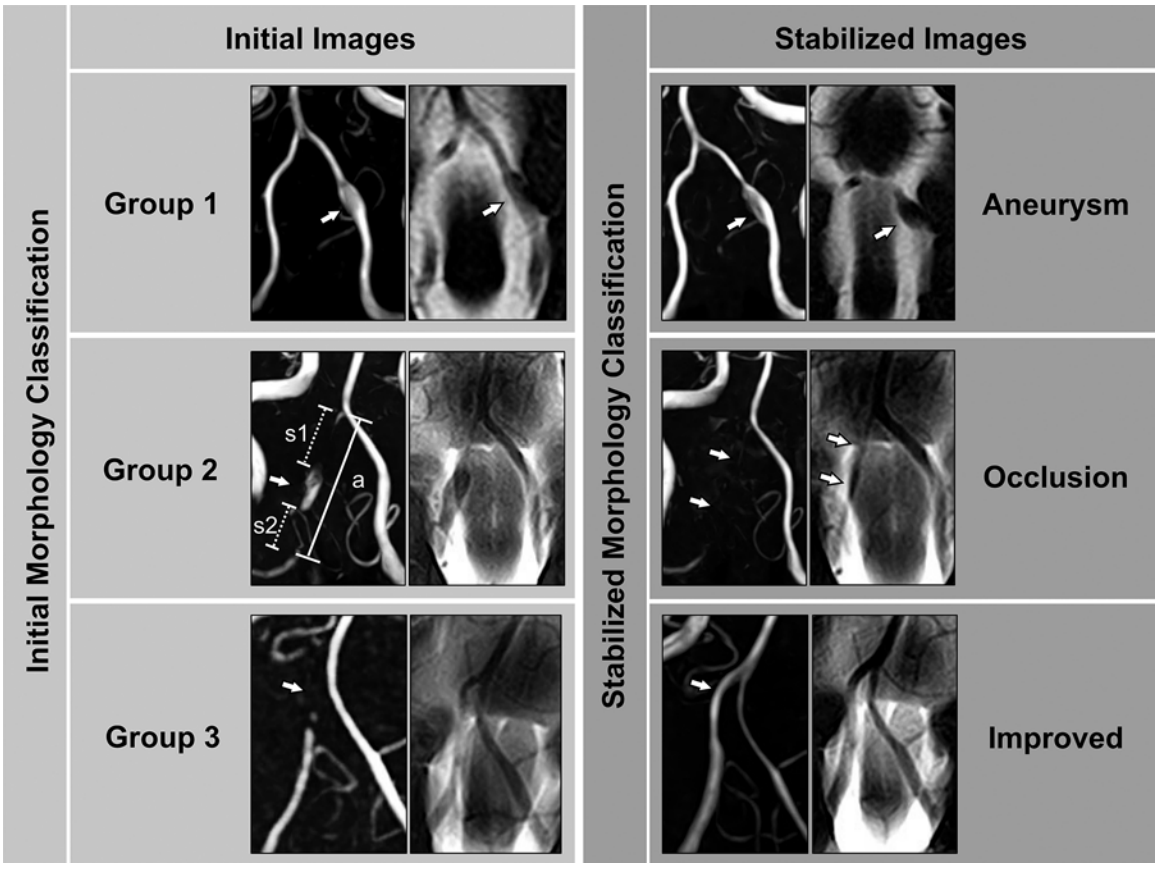

FIG. 1. The representative cases for initial and stabilized vascular morphology classification. Group 1: aneurysm dilatation without stenosis; group 2: aneurysm dilatation with stenosis; group 3: no aneurysm dilatation. In group 2, the *solid line* (a) represents the lesion length, and the *dashed lines* (s1, s2) represent the stenotic section length. *Arrows* indicate lesions. As defined in the text, an aneurysm with stenotic lesions is identified when the condition (s1 + s2)/a > 0.5 is met.

proved, absence of aneurysm formation or vessel occlusion or when a false lumen had disappeared, and the vessel wall became smooth and was considered stable.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (version 28.0, IBM Corp.). Clinical and radiological characteristics and outcomes were analyzed using Pearson's chi-square test for categorical variables and the Kruskal-Wallis test for continuous variables. The periods until the image morphology stabilized, the aneurysm remained, and surgical treatment had been performed were analyzed using the log-rank method for cumulative hazards. Associations between remaining aneurysms, clinical and radiological presentation at diagnosis, and other possible confounders (age, sex, hypertension, smoking status, PICA involvement, double lumen, intramural hematoma, and initial vascular morphology) were evaluated using the logistic regression model. Statistical significance was determined as two-sided p values < 0.05 for a 95% confidence interval.

Results

Figure 2 is a flowchart showing the patient selection process. In total, 159 patients were diagnosed with headache-onset cerebrovascular artery dissection. Of these, 27 cases (unspecified onset or suspected old lesion: 23 cases, extracranial VA dissection: 2 cases, and ischemic onset: 2 cases) were excluded. In addition, 27 patients could not be followed up until their imaging was confirmed to be stable, but 20 of them provided information about their health status through in-person or telephone interviews. All 20 of these patients were alive as of this study's last survey, had not suffered from SAH or ischemic stroke, and had not received any VAD-related surgical treatment. The remaining 7 patients could not be contacted. The other patients were successfully monitored until their imaging became stable. The medical records of these 105 patients were examined to obtain imaging course and final vascular morphology information.

Clinical and Radiological Manifestations

The clinical and radiological characteristics and outcomes of the 105 patients with isolated headache iVAD are summarized in Table 1. The patients included 52 men and 53 women, with a mean age of 50.4 ± 8.1 years. The median interval from headache onset to the first visit was 6 (IQR 4–10) days. Overall, 72 patients (69%) had a history of hypertension. All lesions were confined to the intracranial

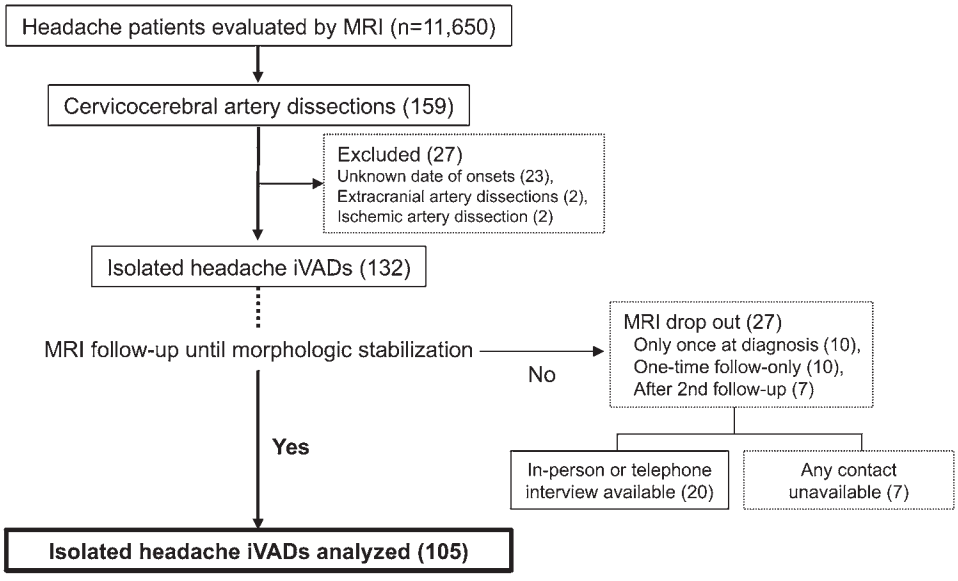

FIG. 2. Flowchart of the patient selection process.

TABLE 1. Clinical and radiological characteristics stratified by initial vascular morphology

Variable	Group 1	Group 2	Group 3	All Patients	p Value
No. of patients	41	45	19	105	
Age in yrs (range)	51.4 ± 7.3 (37–67)	49.8 ± 8.9 (26–83)	49.1 ± 8.0 (28–59)	50.4 ± 8.1 (26–83)	0.88
Male sex	23 (56)	19 (42)	10 (53)	52 (50)	0.42
Past medical history					
Hypertension	27 (66)	34 (76)	11 (58)	72 (69)	0.34
Diabetes	0 (0)	0 (0)	0 (0)	0 (0)	—
Current smoking	11 (27)	12 (27)	5 (26)	28 (27)	0.99
Onset to 1st visit in days	6 (3–12)	7 (2–10)	4.5 (2–10)	6 (4–10)	0.37
Rt laterality of lesion	26 (63)	29 (64)	7 (37)	62 (59)	0.093
Relationship w/ PICA					0.37
PICA-distal	11 (27)	13 (29)	4 (21)	28 (27)	
PICA involved	8 (20)	16 (36)	5 (26)	29 (28)	
PICA-proximal	8 (20)	2 (4)	3 (16)	13 (12)	
Non-PICA	14 (34)	14 (31)	7 (37)	35 (33)	
Diagnostic findings (multiple findings possible)	34 (83)	33 (73)	13 (68)	80 (76)	0.39
Double lumen	20 (49)	29 (64)	13 (68)	62 (59)	0.22
Intramural hematoma					
Total FU period in days	475 (138–1457)	385 (135–1017)	652 (142–793)	478 (143–1094)	0.71
Any stroke-related VAD	0 (0)	0 (0)	0 (0)	0 (0)	—
Antiplatelet use	0 (0)	3 (7)	0 (0)	3 (3)	0.067
Surgical intervention	3 (7)	0 (0)	0 (0)	3 (3)	0.067
Final MRI presentation					**<0.001**
Aneurysm	17 (41)	6 (13)	0 (0)	23 (22)	
Occlusion	0 (0)	13 (29)	7 (37)	20 (19)	
Improved	24 (59)	26 (58)	12 (63)	62 (59)	

FU = follow-up.
Values are expressed as mean ± SD, number (%), or median (IQR), unless indicated otherwise. Boldface type indicates statistical significance.

TABLE 2. Summary of 3 surgical cases

Case No.	Age (yrs)/ Sex	Morphology Classification Group	Bleb	Onset to 1st Visit (days)	Initial Max Size (mm)	Time From Disease Onset to Intervention Decision (days)	Max Size at Intervention (mm)	Summary of Clinical Course
1	54/F	1	No	13	6.5	1152	8.6	Slowly increasing aneurysm for about 4 yrs; flow alteration w/ flow diverter performed
2	50/M	1	No	3	6.3	729	12.2	MRI showed continuous hyperintense intramural hematoma of false lumen & slow aneurysm enlargement; treated w/ stent-assisted coil embolization
3	47/M	1	No	2	12.3	21	12.9	Initial presentation of large, long fusiform aneurysm, which enlarged on day 21; treated w/ stent-assisted coil embolization

vertebral artery, and none involved the basilar artery. The morphological classification at presentation was as follows: group 1, 41 cases (39%); group 2, 45 cases (43%); and group 3, 19 cases (18%). No cases of occlusion were observed at the initial diagnosis. In addition, VAD diagnostic findings included a double lumen/intimal flap in 80 patients (76%) and intramural hematoma in 62 patients (59%). Patient backgrounds did not differ significantly among groups. Representative cases illustrating the initial and final vascular morphology classifications are shown in Fig. 1.

Results of Imaging Trends and Treatment

Patients were followed up for a median of 478 (IQR 143–1094) days, with a median time from disease onset to morphological stability of 75 (IQR 48–140) days. None of the patients developed SAH or stroke during follow-up. In total, 3 patients in group 2 had progressive stenosis with PICA involvement and were treated with antiplatelet agents, but none of them had cerebral infarction. In addition, 3 patients (3%) in group 1 required surgery (endovascular embolization or flow alteration), and treatment decisions were made at 21, 729, and 1152 days from disease onset, respectively (Table 2, Fig. 3, Supplementary Fig. 1).

Regarding the final vascular morphology, approximately 60% of all patients showed improvement. However, there were significant differences in aneurysms and occlusions among groups 1–3, with group 1 the most likely to

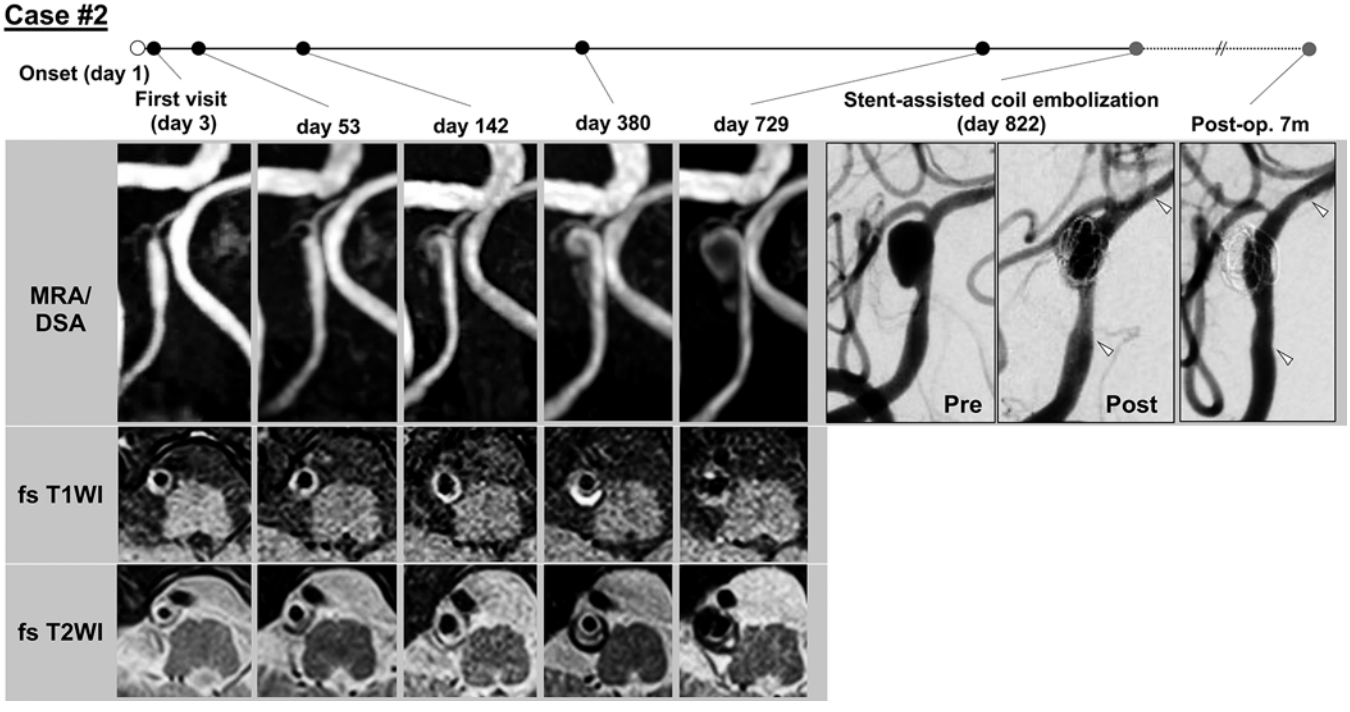

FIG. 3. Case 2. The radiological transition with a continuously enlarged aneurysm from the early onset of isolated headache iVAD to the chronic phase of the disease. Note that fat-suppressed T1-weighted imaging (fs T1WI) showed a hyperintense intramural hematoma continuously spreading to the periphery of the arterial wall. *Arrowheads* in the postoperative images indicate the ends of the stent. m = months; post = postoperatively; pre = preoperatively.

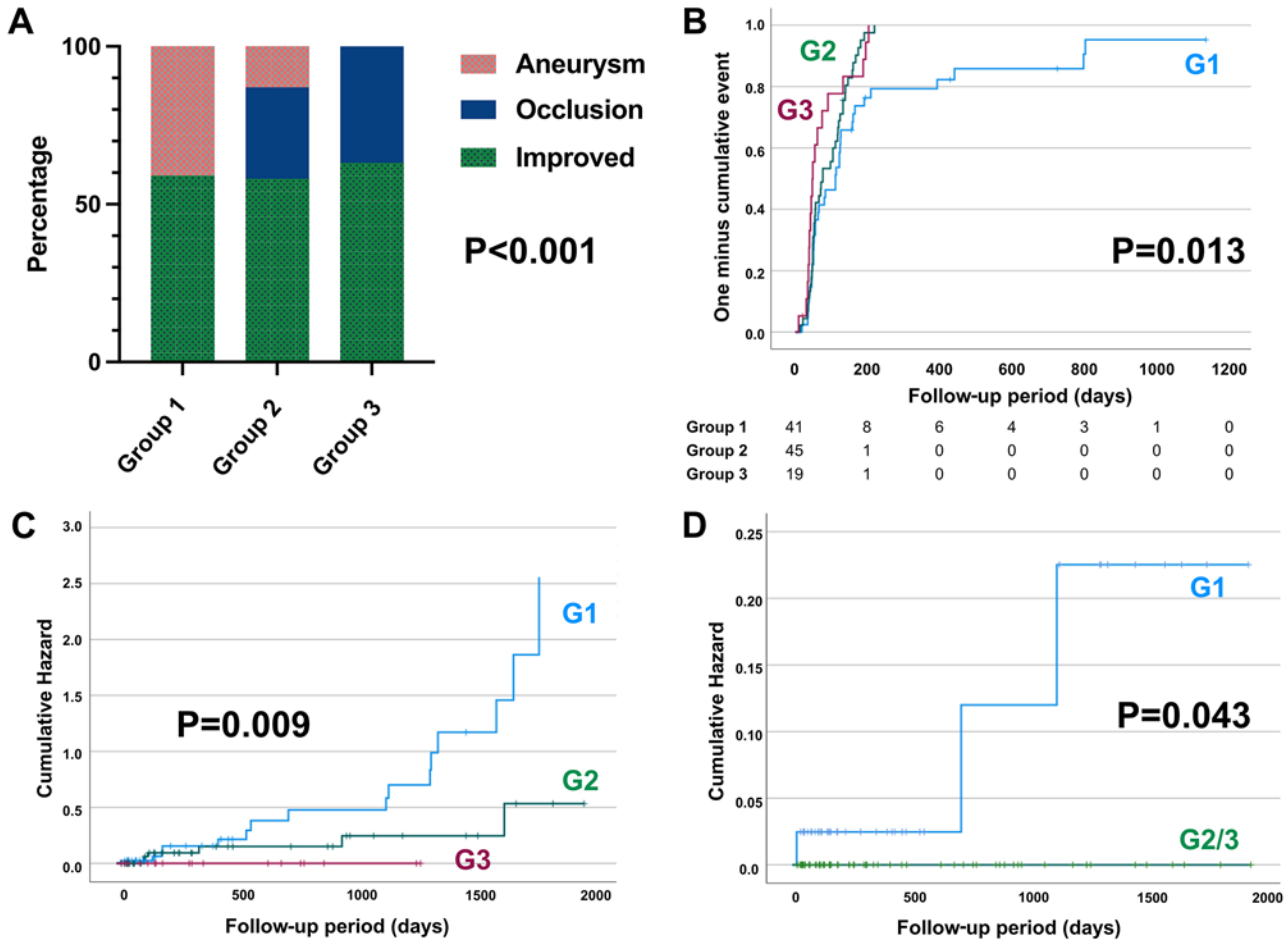

FIG. 4. A: Outcome on the final images in the 3 groups. **B:** Time until image morphology stabilized in the 3 groups. **C:** Cumulative hazard of a residual aneurysm in the 3 groups. **D:** Cumulative hazard of requiring surgical intervention in group 1 (G1) versus non-G1 (G2/3). Figure is available in color online only.

have a residual aneurysm ($p < 0.001$). The log-rank analysis revealed that group 1 patients had significantly longer times to image stabilization ($p = 0.013$) and a greater risk of aneurysm formation ($p = 0.009$) and were more likely to require surgical intervention than the other groups ($p = 0.043$; Fig. 4). Possible parameters were analyzed using binary logistic analysis to identify factors influencing the residual aneurysm (Table 3), and the residual aneurysm risk was significantly associated with the initial vascular morphology in group 1 (OR 7.28, 95% CI 2.30–23.1, $p < 0.001$). Figure 3 and Supplementary Fig. 1 provide detailed imaging follow-up for all 3 patients who underwent surgical intervention (cases 1–3) and illustrate their clinical courses and treatment outcomes, highlighting the importance of angiographic assessment in guiding intervention and posttreatment monitoring.

TABLE 3. Multivariate binary logistic regression model to identify factors associated with a residual aneurysm

Variable	OR	95% CI	p Value
Age >50 yrs	1.22	0.42–3.57	0.72
Male sex	3.08	0.90–10.57	0.07
Hypertension	2.82	0.74–10.8	0.13
Current smoking	0.41	0.15–2.13	0.57
PICA involved	0.90	0.24–3.55	0.92
Double lumen/intimal flap	0.60	0.19–2.62	0.70
Intramural hematoma	0.32	0.20–1.71	0.58
Initial vascular morphology: group 1	7.28	2.30–23.1	**<0.001**

Boldface type indicates statistical significance.

Illustrative Case 2

MRA showed a fusiform aneurysm without stenosis in the right vertebral artery with a maximum diameter of 6.3 mm, leading to the diagnosis of group 1 isolated headache iVAD in a 50-year-old man with no history of hypertension or smoking (Table 2, Fig. 3), who presented to our hospital on the 3rd day after the sudden onset of right occipital-nuchal pain. During the follow-up period, the distal end of the arterial dilatation enlarged gradually, and a hyperintense intramural hematoma that spread to the arterial wall periphery was continuously observed. On day 729, the maximum diameter increased to 12.2 mm, and the patient was referred to another hospital for surgery.

Stent-assisted coil embolization was performed on day 822. Notably, 7 months after the procedure, angiography confirmed aneurysm shrinkage.

Discussion

Clinical Outcomes and Predictors of Residual Aneurysms

In this study, all 105 patients with isolated headache iVAD had favorable prognoses, and none developed SAH or stroke. Patients in group 1 often had residual aneurysm changes and required more extended follow-up periods, with 3 cases requiring prophylactic surgical intervention because of enlarged aneurysms. Residual aneurysms were a critical factor in patient follow-up. Multivariate analysis identified group 1 initial vascular morphology as a significant independent factor for residual aneurysm development. These findings are consistent with previous reports that stenotic lesions (string sign or pearl-and-string sign) heal quickly,[17] whereas aneurysmal lesions have long-lasting morphological changes.[18] In addition, the VAD aneurysm enlargement risk depends on the maximum diameter or an aneurysm size > 10 mm at initial diagnosis.[18] Furthermore, in a study of the natural history of 98 unruptured VAD aneurysms, 5 cases with aneurysm dilatation without stenosis on initial examination developed SAH because of aneurysm dilatation or rupture.[7] These results are similar to those of the present study; however, the previous study did not examine the relationship between initial vascular morphology and prognosis.

Importance of Early Imaging

Appropriate follow-up and treatment are essential, as SAH and cerebral infarction significantly reduce the possibility of a favorable outcome.[19] In this study, the days from disease onset to intervention were highly variable (21, 729, and 1152 days), with case 3 requiring endovascular treatment due to aneurysm enlargement, which was spotted at the second imaging follow-up (day 21) after the initial visit on the 2nd day of headache onset. Given that there are cases of malignant morphological changes early in the course of disease onset, performing imaging follow-up once in the early stages of iVAD onset is essential. Previous reports have shown that ruptures and cerebral infarctions are highly common in the first 3 days after headache onset;[7,20] thus, careful management can be required for cases presenting within 3 days of headache onset.

Long-Term Monitoring and Morphological Stability

The post-VAD dynamic morphological change duration remains unclear. In early small case series, it was thought that in VAD, morphological changes were complete within 2–3 months.[21,22] However, the required follow-up period increased up to 6 months or even 1 year as the number of cases increased.[17,23] Some studies have suggested little need for diagnostic imaging after 2 years because no change has been seen after that period.[13] In the present study, 91 (87%) of the 105 cases were morphologically stable by day 180. However, longer-term follow-up revealed that 6 cases (5.7%) had not reached imaging stability at 1 year, all of which were in group 1.

Pathological Insights and Aneurysm Formation

According to pathological examination, the acute VAD mechanism involves blood invading the internal elastic lamina, leading to widespread disruption.[5,24] The clinical type and shape of arterial dissections are determined by the extent of this disruption,[6] with the dissection plane (pseudolumen) differing from site to site within the artery.[4,5,25] Aneurysms can develop if the dissection goes deep into the vessel wall or if the vessel is pushed into the true lumen, causing narrowing or occlusion.[7] Ruptured iVADs are typically entry-only or entry-exit types, with the latter being more clinically stable due to constant blood flow in the pseudolumen.[5] On the basis of these findings, we speculated the pathological features of groups 1–3 as follows: most of group 1 likely belongs to the entry-only type, which is prone to remain as an aneurysm due to constant hemodynamic stress. In contrast, most of groups 2 and 3 likely belong to the entry-exit type. Group 2 may have a pseudolumen in the deep media, which causes true lumen narrowing and aneurysm changes in areas with high hemodynamic stress on the adventitia but may heal or occlude if blood flow in the pseudolumen stagnates and thrombosis occurs. In group 3, the pseudolumen may be in a shallower media layer, leading to less severe hemodynamic stress and a greater likelihood of healing without aneurysm formation. On the basis of imaging findings, several reports have suggested that intramural hematoma contributes to dissecting aneurysm enlargement.[26,27] No comprehensive examination of morphological changes during the chronic phase has been conducted; however, a study has reported that vessel recanalization within the thickened intima was observed more than 30 days after the initial event, resulting in chronic fusiform aneurysm formation.[9] This pathology may explain the continued observation of hyperintense intramural hematoma and aneurysm enlargement in case 2 of this study.

Predictors of Ischemic Complications

Although no ischemic events were observed in our cohort, it remains important to consider potential predictors of ischemic complications based on initial presentation, as reported in other studies.[2,28] In our study, 102 of 105 patients did not use antithrombotic agents, but none had an ischemic stroke. This suggests that the need for antithrombotic agents may be low to prevent ischemic stroke in patients with VAD presenting only with headache. Additionally, a large review on VAD in 2015 concluded that no specific pattern could be identified for predicting ischemic stroke.[2] Conversely, a retrospective study of 191 cases of unruptured VAD classified into ischemic and nonischemic types at onset revealed that the ischemic type was significantly associated with steno-occlusive angiographic shapes and basilar artery involvement at initial presentation.[28] No significant differences were found in terms of age, sex, medical history, or PICA involvement.

During the management of iVAD, the lesion's location within the V4 segment relative to the PICA should be considered. Our analysis showed no significant differences in aneurysm persistence or the need for surgical intervention based on PICA-related categorizations. Although no ische-

mic events were observed, lesions near the lateral spinal artery, especially with AICA-PICA variation, could theoretically increase the risk of lateral medullary syndrome. In our cohort, 25 (24%) of 105 cases had the AICA-PICA variation. Despite this, no ischemic events occurred, suggesting that other protective factors may be at play.

Follow-Up Imaging Protocol and Management Recommendations

Taken together, our proposed follow-up imaging protocol includes the use of MRI and MRA at specific intervals: at approximately 2 weeks, 2 months, and 6 months after the initial diagnosis. However, for patients presenting within 3 days of symptom onset, the initial follow-up should be more frequent and meticulous. Aneurysms 5 mm or smaller without an enlargement tendency do not require regular imaging follow-up but should be monitored on a case-by-case basis. Aneurysms larger than 5 mm should be followed up every 6–12 months, depending on the degree of aneurysm involvement. Our study identified dilatation without stenosis at initial presentation as a significant risk factor for residual aneurysms and the need for surgical intervention. Therefore, patients with this morphology should be monitored closely. Clinical follow-up should involve regular monitoring of blood pressure, smoking cessation, and limited neck movement. Antithrombotic medications are generally unnecessary. While upfront treatment is not recommended for all patients, those with high-risk features such as rapid aneurysm enlargement or aneurysms > 10 mm should be closely monitored and considered for early intervention. Treatment modalities may include endovascular procedures such as stent-assisted coiling or flow diversion, tailored to individual patient risk factors and symptomatology. Patients should be considered for DSA if they experience a stroke or SAH, if their aneurysm enlarges to approximately 10 mm in size, or if they have an aneurysm with a bleb.

Study Limitations

The limitations of our study include its retrospective design, which may have introduced selection bias, potentially limiting the ability to establish causality between observed factors and outcomes. Additionally, our research was conducted at a single center, potentially limiting the generalizability of the findings to other populations and settings, necessitating multicenter studies to validate our results. While adequate for preliminary analysis, the sample size of 105 patients remains relatively small, particularly when considering subgroups based on initial vascular morphology and lesion location. Moreover, the follow-up duration varied among patients, with the median follow-up of 478 days being potentially insufficient to fully understand the long-term prognosis and potential late complications of iVAD. Future studies should incorporate extended follow-up periods to gain a deeper understanding of the long-term outcomes and the stability of morphological changes, particularly in patients who undergo surgery and exhibit aneurysm changes. Although MRI and MRA were used consistently, the timing and frequency of imaging follow-ups were not uniform across all patients, potentially affecting the assessment of vascular changes and outcomes. Additionally, the loss of 27 patients to follow-up may have introduced bias. Efforts were made to confirm the status of these patients, and 20 were confirmed to have not had VAD-related events; however, the status of the remaining 7 patients remains unknown. Lastly, because no ischemic events were observed in our cohort, our ability to identify predictors of ischemic complications is limited.

Conclusions

Isolated headache iVAD prognosis in patients presenting with a headache was generally favorable, but those with aneurysm dilatation without stenosis at initial presentation should be followed closely, as this group has the highest risk of aneurysm enlargement from early disease onset through the chronic phase. In such cases, patients may require surgical intervention to prevent critical conditions.

Acknowledgments

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References

1. Metso TM, Metso AJ, Helenius J, et al. Prognosis and safety of anticoagulation in intracranial artery dissections in adults. *Stroke*. 2007;38(6):1837-1842.
2. Debette S, Compter A, Labeyrie MA, et al. Epidemiology, pathophysiology, diagnosis, and management of intracranial artery dissection. *Lancet Neurol*. 2015;14(6):640-654.
3. Shibahara T, Yasaka M, Wakugawa Y, et al. Improvement and aggravation of spontaneous unruptured vertebral artery dissection. *Cerebrovasc Dis Extra*. 2017;7(3):153-164.
4. Sikkema T, Uyttenboogaart M, Eshghi O, et al. Intracranial artery dissection. *Eur J Neurol*. 2014;21(6):820-826.
5. Mizutani T, Kojima H, Asamoto S, Miki Y. Pathological mechanism and three-dimensional structure of cerebral dissecting aneurysms. *J Neurosurg*. 2001;94(5):712-717.
6. Mizutani T, Kojima H, Asamoto S. Healing process for cerebral dissecting aneurysms presenting with subarachnoid hemorrhage. *Neurosurgery*. 2004;54(2):342-348.
7. Mizutani T. Natural course of intracranial arterial dissections. *J Neurosurg*. 2011;114(4):1037-1044.
8. Zhao KJ, Fang YB, Huang QH, et al. Reconstructive treatment of ruptured intracranial spontaneous vertebral artery dissection aneurysms: long-term results and predictors of unfavorable outcomes. *PLoS One*. 2013;8(6):e67169.
9. Ono H, Nakatomi H, Tsutsumi K, et al. Symptomatic recurrence of intracranial arterial dissections: follow-up study of 143 consecutive cases and pathological investigation. *Stroke*. 2013;44(1):126-131.
10. Nakajima S, Tsukahara T, Minematsu K. A study of vertebrobasilar artery dissection with subarachnoid hemorrhage. *Acta Neurochir Suppl (Wien)*. 2010;107:45-49.
11. Kashiwazaki D, Ushikoshi S, Asano T, Kuroda S, Houkin K. Long-term clinical and radiological results of endovascular internal trapping in vertebral artery dissection. *Neuroradiology*. 2013;55(2):201-206.
12. Zhao WY, Krings T, Alvarez H, Ozanne A, Holmin S, Las-

jaunias P. Management of spontaneous haemorrhagic intracranial vertebrobasilar dissection: review of 21 consecutive cases. *Acta Neurochir (Wien)*. 2007;149(6):585-596.
13. Kai Y, Hamada J, Morioka M, et al. Dissecting aneurysms of the vertebral artery—angiographic patterns at the dissecting site on balloon test occlusion. *Neuroradiology*. 2012;54(8):857-862.
14. Silbert PL, Mokri B, Schievink WI. Headache and neck pain in spontaneous internal carotid and vertebral artery dissections. *Neurology*. 1995;45(8):1517-1522.
15. Naito I, Iwai T, Sasaki T. Management of intracranial vertebral artery dissections initially presenting without subarachnoid hemorrhage. *Neurosurgery*. 2002;51(4):930-938.
16. Tsukahara T, Minematsu K. Overview of spontaneous cervicocephalic arterial dissection in Japan. *Acta Neurochir Suppl (Wien)*. 2010;107:35-40.
17. Nakagawa K, Touho H, Morisako T, et al. Long-term follow-up study of unruptured vertebral artery dissection: clinical outcomes and serial angiographic findings. *J Neurosurg*. 2000;93(1):19-25.
18. Kobayashi N, Murayama Y, Yuki I, et al. Natural course of dissecting vertebrobasilar artery aneurysms without stroke. *AJNR Am J Neuroradiol*. 2014;35(7):1371-1375.
19. Li S, Yan B, Kaye A, et al. Prognosis of intracranial dissection relates to site and presenting features. *J Clin Neurosci*. 2011;18(6):789-793.
20. Ro A, Kageyama N, Abe N, Takatsu A, Fukunaga T. Intracranial vertebral artery dissection resulting in fatal subarachnoid hemorrhage: clinical and histopathological investigations from a medicolegal perspective. *J Neurosurg*. 2009;110(5):948-954.
21. Kitanaka C, Tanaka J, Kuwahara M, et al. Nonsurgical treatment of unruptured intracranial vertebral artery dissection with serial follow-up angiography. *J Neurosurg*. 1994;80(4):667-674.
22. Akiyama Y, Itoh T, Kumai J, Iwamuro Y, Miyake H, Nishikawa M. Vertebral artery dissection without subarachnoid hemorrhage studied by serial angiography. Article in Japanese. *No Shinkei Geka*. 1996;24(5):443-449.
23. Jeon YS, Cho J, Park JJ, Roh HG, Chun YI. Acute hemicranial pain accompanied with a pearl and string type dissection of intracranial vertebral artery: consideration for the time when to finish the medical observation. *Medicine (Baltimore)*. 2022;101(49):e32008.
24. Mizutani T, Miki Y, Kojima H, Suzuki H. Proposed classification of nonatherosclerotic cerebral fusiform and dissecting aneurysms. *Neurosurgery*. 1999;45(2):253-260.
25. Krings T, Choi IS. The many faces of intracranial arterial dissections. *Interv Neuroradiol*. 2010;16(2):151-160.
26. Mizutani T. A fatal, chronically growing basilar artery: a new type of dissecting aneurysm. *J Neurosurg*. 1996;84(6):962-971.
27. Koyama S, Kotani A, Sasaki J. Giant basilar artery aneurysm with intramural hemorrhage and then disastrous hemorrhage: case report. *Neurosurgery*. 1996;39(1):174-178.
28. Kim BM, Kim SH, Kim DI, et al. Outcomes and prognostic factors of intracranial unruptured vertebrobasilar artery dissection. *Neurology*. 2011;76(20):1735-1741.

Disclosures

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: Oshima, Higurashi. Acquisition of data: Oshima, Higurashi, Asada, Yamada. Analysis and interpretation of data: Oshima, Higurashi, Takase. Drafting the article: Oshima, Yamamoto. Critically revising the article: Tateishi. Reviewed submitted version of manuscript: Takase, Tateishi. Approved the final version of the manuscript on behalf of all authors: Oshima. Statistical analysis: Oshima, Takase. Study supervision: Oshima, Higurashi, Yamamoto.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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