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Screening for Mild Vertebral Artery Dissection Using 3-Dimensional T1-weighted Black-blood Magnetic Resonance Imaging: A Retrospective Observational Study of 3,049 Consecutive Walk-in Patients Presenting with Headache

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Abstract

Vertebral artery dissection is a rare but potentially life-threatening condition. However, many cases of mild vertebral artery dissection—an early disease stage—may be overlooked. 3-dimensional T1-weighted black-blood magnetic resonance imaging has recently emerged as a promising diagnostic tool, yet it remains underutilized. This study investigated the impact of vertebral artery dissection screening in patients presenting with headache, the most common chief complaint encountered in general neurosurgery outpatient clinics, and an initial symptom of vertebral artery dissection, in a real-world clinical setting. We retrospectively reviewed 3,049 consecutive patients with headache who visited a neurosurgical outpatient center in Chiba, Japan (October 2021-October 2023). In the first year, 1,527 patients underwent brain magnetic resonance imaging and magnetic resonance angiography. In the second year, 1,522 patients received these examinations as well as brain and neck black-blood magnetic resonance imaging. Vertebral artery dissection detection rates were compared between the 2 groups.

Vertebral artery dissection was diagnosed in 0.5% and 1.6% of the former and latter groups, respectively (relative risk: 3.42, 95% confidence interval 1.48-7.92, p = 0.003), indicating an over threefold increase in detection. Among patients with intracranial vertebral artery dissection, 96% reported occipital headache rather than nonspecific/generalized headache. Among high-risk individuals aged 40-55 years with occipital or posterior neck pain, the detection rate reached 7.5%. Vertebral artery dissection accounted for 93% of head and neck arterial dissections. The addition of black-blood magnetic resonance imaging significantly improved early detection and may enhance screening accuracy for patients presenting with headache at elevated risk.

Keywords: vertebral artery dissection, headache, magnetic resonance imaging, magnetic resonance angiography, intracranial arterial disease

Introduction

Headache is a common neurological disorder affecting 1 in 2 people in developed countries, with a reported incidence of 1,100 per 100,000 individuals. Patients with vertebral artery dissection (VAD) represent a small subset of this population.[1,2)]

VAD is recognized as a rare but potentially fatal vascular condition, with an estimated incidence of 1 to 2 per 100,000 individuals.[3-5)] In Western countries, carotid artery

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dissection (CAD) is commonly observed, and its pathophysiology and therapeutic strategies have been extensively studied.[6-8] In contrast, clinical observations in Japan suggest that VAD is overwhelmingly more prevalent in headache clinics, whereas CAD is infrequently diagnosed.[7]

VAD is typically reported in severe clinical presentations, including subarachnoid hemorrhage, intracerebral hemorrhage, and cerebral infarction.[9-11] The clinical profile of VAD remains poorly defined, although a substantial number of patients may present with mild forms of the disease manifesting merely as a headache.

The standard diagnostic approach for VAD primarily relies on digital subtraction angiography, which is often supplemented with magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and 3-dimensional computed tomography angiography (CTA). However, early-stage VAD and minute mural thrombi may be overlooked using these conventional techniques.[12,13]

Three-dimensional T1-weighted black-blood MRI (BB MRI) has recently been developed for the evaluation of cervical atherosclerotic plaques and deep vein thrombosis (DVT).[14] This noninvasive imaging technique enhances visualization of mural thrombi by directly visualizing the vessel wall while suppressing the signal from flowing blood in the lumen and has demonstrated improved diagnostic yield.[15,16] However, no large-scale investigations have assessed the utility of BB MRI in identifying mild VAD in patients presenting exclusively with headache.

Given the limited awareness of the clinical utility of BB MRI in detecting mild VAD, we conducted a retrospective study to evaluate its effectiveness as a first-line screening modality in a large cohort of walk-in patients presenting with headache as their chief complaint.

Materials and Methods

Study design

We retrospectively analyzed the clinical records of 3,049 consecutive walk-in patients who presented with headache. Headache was defined according to the criteria of the International Classification of Headache Disorders, 3rd edition. The inclusion criterion for MRI examination was patients with headache who requested an MRI, regardless of red flags in either the acute or chronic phase. This approach was adopted to minimize inherent selection bias among patients visiting the neurosurgery outpatient center. The exclusion criteria of MRI examination were as follows: contraindications for MRI evaluation, including use of cardiac pacemakers, implantable cardioverter-defibrillators, ventriculoperitoneal shunts, lumboperitoneal shunts, cochlear implants, or a history of coronary stent placement within 8 weeks. After applying these criteria, data on 3,049 MRI examinations performed on the patients' initial visit day, although some patients (none with VADs) had undergone MRIs prior to the study period.

Clinical records of these 3,049 patients were reviewed to extract demographic data (race, age, sex), medical history, and headache characteristics (sudden onset, pulsatile quality, and occipital pain). For patients with confirmed mild VAD and false-positive VAD, additional data included the presence/absence of neurological deficits, time from onset to presentation, presence/absence of lateral correspondence between pain location and imaging findings, and presence/absence of migraine history.

Follow-up and prognostic data for patients with confirmed mild VAD and false-positive VAD were collected from clinical records, referral hospitals, and telephone questionnaires administered to the patients.

This study was conducted at a neurosurgical outpatient center in Chiba, Japan, over a 2-year period between October 2021 and October 2023.

Based on reports supporting the efficacy of BB MRI in detecting VAD, we incorporated brain and neck BB MRI into the diagnostic protocol for patients presenting with headache beginning September 22, 2022. Patients were retrospectively divided into 2 groups based on the timing of BB MRI implementation, and mild VAD detection rates were compared between these groups.

- MRI+MRA group (October 1, 2021, to September 21, 2022): underwent brain MRI (axial fluid-attenuated inversion recovery, diffusion-weighted imaging, T2*-weighted imaging) and brain MRA.
- MRI+MRA+BB group (September 22, 2022, to October 30, 2023): underwent the above imaging plus brain and neck BB MRI.

The primary outcomes were the detection rate of mild VAD among patients presenting with headache and the diagnostic impact of BB MRI (expressed as relative risk).

The secondary outcomes were the estimated prevalence of arterial dissection at each anatomical site in the head and neck and the identification of high-risk subgroups for mild VAD.

BB MRI findings were interpreted in conjunction with MRA findings and clinical information, reflecting routine practice rather than a blinded independent assessment.

3D T1-weighted BB MRI

BB MRI suppresses the signal from flowing blood, thereby enhancing visualization of the vessel wall and intramural hematoma. Compared to MRA and CTA, BB MRI offers superior sensitivity for detecting intramural hematomas associated with VAD. Prior studies have validated its diagnostic utility in VAD detection.[15,16] All imaging was performed using a Magnetom Sempra 1.5 Tesla scanner (Siemens, Munich, Germany). For brain and neck MRI, coronal T1-weighted 3-dimensional (3D) turbo spin echo sequences were applied, incorporating variable refocusing flip angles and spectral attenuated inversion recovery fat suppression. The imaging range spanned from the subclavian artery to the intracranial M2 segment. Imaging pa-

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rameters were as follows: repetition time/echo time 520/11 ms; flip-angle mode T1 variable; matrix size 256 × 230; slice thickness 1.0 mm; number of slices 112; echo train length 35; bandwidth 651 Hz/pixel; blood suppression gradients (read, phase, slice) 400 mT・ms^2/m; parallel imaging acceleration factor 2; total acquisition time 4 minutes.

Definition of mild VAD

A definitive diagnosis of VAD requires pathological confirmation, which is not feasible in living patients.

In clinical settings, VAD is diagnosed based on radiological criteria outlined by the American Heart Association/American Stroke Association and the European Federation of Neurorehabilitation Societies. These criteria include findings such as intramural hematoma, intimal flap, double lumen, tapered narrowing, or pseudoaneurysm, as visualized on MRI, MRA, or CTA.[17,18] For this study, mild VAD was defined by the presence of all of the following criteria:

(i). Absence of intracranial complications (such as subarachnoid hemorrhage or cerebral infarction) and no neurological deficits beyond headache at initial presentation;

(ii). For the MRI+MRA group: (a) presence of characteristic MRA features such as intimal flap, double lumen, tapered narrowing, pseudoaneurysm, or fusiform (aneurysmal) dilatation.

For MRI+MRA+BB group: either (a) above or (b) positive BB MRI findings in any V2-V4 segment, or both (a) and (b).

(iii). In cases with suspected false-positive VAD, follow-up imaging was performed for more than 6 months to assess morphological changes, and patients who exhibited either worsening or improvement were considered VAD-positive.

The initial diagnosis was made by a neurosurgeon at a neurosurgical outpatient center in Chiba, Japan, with more than 20 years of experience. Of the 40 patients (including suspected false-positive VAD cases), 39 were referred, along with MRI images, to the neurosurgery departments of core hospitals for independent confirmation.

Statistical methods

We used JMP version 12.0.1 to perform statistical analysis, including Student's t-test, Chi-square test, Fisher's exact test, and multivariate logistic regression. Statistical significance was defined as $P < 0.05$.

Ethics approval

This study received approval from the Institutional Review Board of Chiba University Graduate School of Medicine, Chiba, Japan (Approval No.: M10847). As this was a retrospective study, informed consent was obtained through an opt-out system.

Results

Patient characteristics and mild VAD detection rates

More than 99% of patients were of Asian ancestry, predominantly Japanese. Table 1 presents patient demographics and screening outcomes. Variables compared between the MRI+MRA group and the MRI+MRA+BB group included age, sex, hypertension, hyperlipidemia, diabetes mellitus, history of stroke, cardiovascular disease, atrial flutter, cancer, smoking status, and alcohol consumption. Student's t-test and chi-square analysis revealed no statistically significant differences in patient characteristics between the 2 groups.

Intracranial screening detected mild VAD in 7 patients within the MRI+MRA group. In the MRI+MRA+BB group, mild VAD was diagnosed using MRI+MRA alone (without BB MRI) in 9 patients: 4 with MRA-positive and BB-negative findings (cases 8-11; Table 3) and 5 with MRA-positive and BB-positive findings (cases 12-16). No significant difference was observed between these 2 groups (relative risk: 1.29; 95% confidence interval [CI]: 0.48-3.45, p = 0.628). However, when BB MRI was performed, additional cases were detected: 11 patients with MRA-equivocal and BB-positive findings (cases 17-27) and one patient with MRA-negative and BB-positive findings (case 28). These patients, who were difficult to diagnose by MRA alone, were determined to be positive for mild VAD. In total, 21 patients were diagnosed in the MRI+MRA+BB group compared to 7 patients in the MRI+MRA group, demonstrating a significant improvement in diagnostic accuracy (relative risk: 3.01; 95% CI: 1.28-7.06, p = 0.008).

Mild VAD involving the extracranial artery was definitively diagnosed in 7 patients in the MRI+MRA group and in 25 patients in the MRI+MRA+BB group. Fisher's exact test demonstrated a statistically significant increase in mild VAD detection with BB MRI (relative risk: 3.42; 95% CI: 1.48-7.92, p = 0.003).

Prevalence of dissection of different arteries in the head and neck

Mild VAD was detected in 25 patients, whereas CAD was reported in only 2 patients in the MRI+MRA+BB group. No BB MRI-positive findings were observed in other major intracranial arteries, including the anterior, middle, and posterior cerebral arteries, in any patient. Differentiation from reversible cerebral vasoconstriction syndrome was difficult, and no cases met the criteria for definitive diagnosis of arterial dissection in these vessels. Mild VAD accounted for 93% of all head and neck arterial dissection cases (25 VAD cases/25 VAD cases + 2 CAD cases = 0.93).

Clinical features of diagnosed mild VAD and false-positive cases

Table 3 summarizes all confirmed cases of VAD in the brain and neck. All 32 cases were classified as mild VAD,

Table 1 Main Analysis of Patient Demographics and Comparison of Mild Vertebral Artery Dissection Screening Methods in Consecutive Headache Patients, 2021-2023 (n = 3,049)

	MRI+MRA	MRI+MRA+BB
No. of patients (n)	1,527	1,522
Study period	Oct 1, 2021-Sep 21, 2022	Sep 22, 2022-Oct 30, 2023
Patient Characteristics:		
Age, years, mean±SD [95% CI]	48.3±18.4 [47.3-49.2]	47.3±18.4 [46.4-48.2]
Male sex, n (%)	544 (35.6%)	591 (38.8%)
Hypertension, n (%)	311 (20.4%)	303 (20.0%)
Hyperlipidemia, n (%)	213 (14.0%)	180 (11.9%)
Diabetes mellitus, n (%)	72 (4.7%)	62 (4.1%)
Stroke history, n (%)	72 (4.7%)	49 (3.2%)
Cardiovascular disease, n (%)	24 (1.6%)	14 (0.9%)
Atrial flutter, n (%)	20 (1.3%)	11 (0.7%)
Cancer history, n (%)	74 (4.8%)	55 (3.6%)
Smoking history*, n (%)	36/97 (37.1%)	38/124 (30.6%)
Alcohol use*, n (%)	30/97 (30.9%)	40/127 (31.5%)
Screening result:		
VAD-suspected findings (a), n (%)	7 (0.5%)	33 (2.2%)
False positives (b), n (%)	0 (0%)	8 (0.5%)
Confirmed VAD (a-b), n (%)	7 (0.5%)	25 (1.6%)
Intracranial VAD, n (%)	7 (0.5%)	21 (1.4%)
MRA positive, BB negative	NA	4 (0.3%)
MRA positive, BB positive	NA	5 (0.3%)
MRA equivocal, BB positive	NA	11 (0.7%)
MRA negative, BB positive	NA	1 (0.1%)
Extracranial VAD, n (%)	NA	4 (0.3%)

BB: black-blood MRI; CI: confidence interval; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging; NA: not applicable; Oct: October; SD: standard deviation; Sep: September; VAD: vertebral artery dissection
*Data available only for a subset of patients who provided detailed lifestyle histories.

with 28 (87.5%) involving the intracranial V3-V4 segment. The mean time from onset to presentation was 8.8 days. The extracranial V2 segment was affected in 4 cases, all within the MRI+MRA+BB group, as the MRI+MRA group did not include neck imaging. Morphologically, the MRI+MRA group predominantly exhibited the classic "pearl and string" sign (71.4%). In contrast, the MRI+MRA+BB group identified smaller VADs, including subtle stenosis, mild dilatation, or arteries with barely discernible changes on brain MRA, due to the complementary use of brain and neck BB MRI. Symptomatically, 27 of 28 patients (96%) with V3-V4 involvement reported occipital headache. Cases involving the V2 segment presented with more variable symptoms.

Regarding intracranial lesions, only 1 patient reported bilateral occipital headache. When this patient was included, pain lateralization matched vertebral artery involvement in all 26 patients (100%).

A sudden onset or date-certain onset was observed in 23/28 patients (82%). Pulsatile headache and a history of migraine were observed in 14/27 (52%) and 17/27 (63%) patients, respectively—features insufficient to reliably suspect mild VAD.

Follow-up data (outpatient follow-up visits, follow-up surveys, and telephone questionnaires as of November 15, 2025) for the 32 patients with confirmed mild VAD demonstrated the following findings. Four patients exhibited temporary worsening of imaging findings, and 3 had vertebral artery occlusion (2 with occlusion and healing). One patient (case 22) demonstrated transient neurological deterioration. In one patient (case 14), both imaging findings and neurological symptoms of mild VAD initially normalized, but contralateral CAD (C5) developed 13 months later. Two patients received medical interventions. One patient (case 22) developed vertebral artery occlusion and medullocerebellar infarction 1 month post-diagnosis and

Table 2 Subgroup Analysis of High-Risk Patients and Characteristics of Confirmed Mild VAD Cases

	Age 40-55 years with OP or posterior neck pain	All confirmed mild VAD cases
No. of patients (n)	200/1,522	32/3,049
Study period	Sep 22, 2022-Oct 30, 2023	Oct 1, 2021-Oct 30, 2023
Patient characteristics:		
Age, years, mean±SD [95% CI]	47.9±4.3[47.3-48.5]	48.6±7.3[46.0-51.3]
Male sex, n (%)	92 (41.3%)	13 (40.6%)
Hypertension, n (%)	49 (22.0%)	4 (12.5%)
Hyperlipidemia, n (%)	18 (8.1%)	3 (9.4%)
Diabetes mellitus, n (%)	7 (3.1%)	1 (3.1%)
Stroke history, n (%)	7 (3.1%)	0 (0.0%)
Cardiovascular disease, n (%)	2 (0.9%)	0 (0.0%)
Atrial flutter, n (%)	1 (0.5%)	1 (3.1%)
Cancer history, n (%)	2 (0.9%)	0 (0.0%)
Smoking history*, n (%)	8/15 (53.3%)	7/9 (78%)
Alcohol use*, n (%)	6/13 (46.1%)	5/9 (55.6%)
Screening result:		
Confirmed VAD, n (%)	17 (8.5%)	32 (1.1%)
Intracranial VAD, n (%)	15 (7.5%)	28 (0.9%)

CI: confidence interval; Oct: October; OP: occipital pain; SD: standard deviation; Sep: September; VAD: vertebral artery dissection
*Data available only for a subset of patients who provided detailed lifestyle histories.

underwent endovascular stenting. In another patient (case 10), vertebral artery dilatation increased 31 months later, and a stent was placed. Five patients (cases 3, 13, 28, 29, and 31) dropped out early during the follow-up, though full recovery was subsequently confirmed in 4 of them. To the best of our knowledge, all patients had a favorable prognosis with a Modified Rankin Scale score of 0.

Seven of 8 false-positive patients showed no morphological changes. Cases 33 and 35 had stable, high-intensity dots on BB MRI consistent with arteriosclerosis. In case 34, VAD was ruled out by the neurosurgeon at the referral hospital. Case 39 was initially diagnosed as mild VAD but showed no changes over time. Case 40 exhibited features strongly suggestive of mild VAD, but follow-up at the referral hospital revealed no morphological changes. Thus, these 2 cases (cases 39 and 40) were placed in the gray zone.

False-positive cases were distinguished from confirmed mild VAD cases by relatively older age, unclear onset, nonspecific symptoms (e.g., head heaviness), variable pain locations, and absence of morphological changes.

Figure 1 illustrates 2 representative cases of intracranial mild VAD, 1 case of extracranial mild VAD, and 2 false-positive cases.

Predictive factors and identification of high-risk patients

Table 4 lists predictive factors for mild VAD identified through multivariate logistic regression analysis. Statistically significant independent associations were observed for BB MRI use, age, and pain location. No significant associations were found for sex, presence of hypertension, or presence of hyperlipidemia.

Other variables, including diabetes mellitus and cardiovascular disease, were not associated with mild VAD cases. Smoking history and alcohol consumption were excluded from analysis due to small sample sizes and statistical instability.

Among patients aged 40-55 years presenting with occipital or posterior neck pain, the mild VAD detection rate in the MRI+MRA+BB group increased to 7.5%.

We performed a subgroup analysis of 200 patients aged 40-55 years presenting with apparent occipital or posterior neck pain (Table 2). Multivariate logistic regression analysis identified no significant predictors. Univariate analysis identified smoking history as a significant factor ($p = 0.045$, odds ratio [OR]: 3.01 [1.00-9.02]). In the subgroup analysis of all 32 patients with mild VAD, 7 of 9 patients (78%) had a smoking history, the prevalence of which was significantly higher compared to that in 3,017 VAD-negative patients ($p = 0.008$, OR: 7.46 [1.51-36.8]).

Table 3 Clinical and Imaging Characteristics of Mild VAD Cases and False-Positive Cases

Case	Age/Sex	Diagnosis	Modality	Duration from onset (day)	Region of VAD	Features of head MRA	Features of BB MRI	Chief complaint	Headache pattern				Image changes during follow-up	Temporary neurological deterioration	Follow-up (month)	Final outcome (mRS)
									Pain-VAD laterality match	Onset	Pulsatile	Migraine history				
1	40/F	VAD	MRA	4	V4	fusiform dilatation	NA	OP	NA	sudden	NA	(+)	normalized	(-)	41	SR (0)
2	53/M	VAD	MRA	5	V4	tapered stenosis	NA	OP	(+)	date-certain	NA	NA	temporary P&S	(-)	5	SR (0)
3	35/M	VAD	MRA	2	V4	P&S	NA	parietal pain	(+)	sudden	(+)	(-)	improved	(-)	1	SR (0)
4	41/F	VAD	MRA	5	V4	P&S	NA	OP	(+)	date-certain	(+)	(-)	normalized	(-)	36	SR (0)
5	52/F	VAD	MRA	3	V4	P&S	NA	OP	(+)	sudden	(+)	(+)	normalized	(-)	12	SR (0)
6	56/F	VAD	MRA	11	V4	P&S	NA	OP	(+)	sudden	(+)	(-)	temporary occlusion	(-)	24	SR (0)
7	45/F	VAD	MRA	4	V4	P&S	NA	OP	NA	date-certain	NA	(+)	occlusion	(-)	12	SR (0) *
8	53/M	VAD	MRA+BB	11	V4	fusiform dilatation	normal	OP	(+)	date-certain	NA	(-)	improved	(-)	26	SR (0)
9	44/F	VAD	MRA+BB	6	V4	double lumen	normal	OP	(+)	date-certain	(+)	(+)	NC	(-)	33	SR (0)
10	58/F	VAD	MRA+BB	2	V4	fusiform dilatation	normal	OP	(+)	date-certain	(-)	(+)	worsened	(-)	31	IR (0) ‡
11	51/F	VAD	MRA+BB	1	V4	fusiform dilatation	normal	OP	(+)	sudden	(-)	(+)	normalized	(-)	21	SR (0)
12	48/F	VAD	MRA+BB	14	V4	P&S	HI	OP	(+)	date-certain	(-)	(+)	P&S organized	(-)	26	SR (0)
13	43/M	VAD	MRA+BB	7	V4	double lumen	HI	OP	(+)	unclear	(+)	(+)	NC	(-)	2	SR (0)
14	54/F	VAD	MRA+BB	9	V3	double lumen	HI	OP	(+)	date-certain	(+)	NA	normalized	(-)	10	SR (0) †
15	38/F	VAD	MRA+BB	6	V4	double lumen	HI	OP	(+)	date-certain	(-)	(-)	temporary occlusion	(-)	14	SR (0)
16	50/F	VAD	MRA+BB	3	V4	pseudo aneurysm	HI	OP	(+)	date-certain	(+)	(+)	occlusion	(-)	7	SR (0) *
17	56/F	VAD	MRA+BB	14	V4	stenosis	slight HI	OP	(+)	unclear	(-)	(+)	normalized	(-)	8	SR (0)
18	50/M	VAD	MRA+BB	5	V4	fusiform dilatation	HI	OP	(+)	date-certain	(+)	(+)	NC	(-)	6	SR (0)
19	43/M	VAD	MRA+BB	11	V4	slight P&S	HI	OP	(+)	sudden	(-)	NA	temporary worsened	(-)	10	SR (0)
20	62/M	VAD	MRA+BB	41	V4	slight double lumen	HI	OP	(+)	sudden	(-)	NA	normalized	(-)	18	SR (0)
21	33/M	VAD	MRA+BB	10	V4	slight dilatation	HI	OP	(+)	sudden	(-)	(+)	NC	(-)	38	SR (0)
22	54/M	VAD	MRA+BB	7	V4	slight stenosis	HI	OP	(+)	unclear	(-)	(+)	worsened	vertigo	20	IR (0) §

Table 3 Clinical and Imaging Characteristics of Mild VAD Cases and False-Positive Cases (continued)

Case	Age/Sex	Diagnosis	Modality	Duration from onset (day)	Region of VAD	Features of head MRA	Features of BB MRI	Chief complaint	Headache pattern: Pain-VAD laterality match	Headache pattern: Onset	Headache pattern: Pulsatile	Headache pattern: Migraine history	Image changes during follow-up	Temporary neurological deterioration	Follow-up (month)	Final outcome (mRS)
23	49/F	VAD	MRA+BB	5	V4	slight stenosis	HI	OP	(+)	date-certain	(+)	(+)	normalized	(-)	9	SR (0)
24	50/M	VAD	MRA+BB	7	V4	very slight stenosis	HI	OP	(+)	unclear	(-)	TTH	normalized	(-)	14	SR (0)
25	54/F	VAD	MRA+BB	8	V4	very slight stenosis	HI	OP	(+)	date-certain	(+)	(+)	normalized	(-)	31	SR (0)
26	40/M	VAD	MRA+BB	11	V4	very slight dilatation	HI	OP	(+)	date-certain	(+)	(-)	normalized	(-)	31	SR (0)
27	57/F	VAD	MRA+BB	14	V4	very slight stenosis	HI	OP	(+)	date-certain	NA	TTH	normalized	(-)	20	SR (0)
28	55/M	VAD	MRA+BB	7	V4	almost normal	HI	OP	(+)	unclear	(-)	NA	normalized	(-)	1	SR (0)
29	44/F	VAD	MRA+BB	20	V2	normal	HI	p.neck pain	(+)	unclear	(+)	(+)	NA	NA	NA	NA
30	40/F	VAD	MRA+BB	14	V2	normal	HI	eye, ear pain	(+)	unclear	(-)	TTH	normalized	(-)	19	SR (0)
31	50/F	VAD	MRA+BB	15	V2	normal	HI	p.neck pain	(+)	date-certain	(-)	(-)	NA	(-)	0	SR (0)
32	58/F	VAD	MRA+BB	1	V2	normal	HI	frontal pain	NA	date-certain	(+)	(+)	normalized	(-)	9	SR (0)
33	63/M	FP	MRA+BB	2	V4	slight dilatation	HI	OP	(+)	sudden	NA	NA	NC	(-)	14	SR (0)
34	59/F	FP	MRA+BB	7	V4	slight dilatation	slight HI	OP	(+)	unclear	(+)	(-)	NA	NA	0	SR (0)
35	81/F	FP	MRA+BB	30	V4	slight dilatation	slight HI	temporal pain	(+)	unclear	NA	(-)	NC	(-)	9	SR (0)
36	60/F	FP	MRA+BB	14	V4	slight stenosis	normal	OP	(+)	unclear	(-)	NA	NC	(-)	16	SR (0)
37	73/M	FP	MRA+BB	11	V4	fusiform dilatation	normal	heaviness	(-)	unclear	(-)	(-)	NC	(-)	14	SR (0)
38	54/F	FP	MRA+BB	30	V4	fusiform dilatation	normal	heaviness	(-)	unclear	(-)	NA	NC	(-)	12	SR (0)
39	55/M	FP	MRA+BB	5	V4	fusiform dilatation	slight HI	OP	(+)	date-certain	NA	NA	NC	(-)	19	SR (0)
40	48/F	FP	MRA+BB	20	V4	tapered stenosis	HI	OP	(+)	unclear	NA	NA	NC	(-)	21	SR (0)

BB: black-blood MRI; F: female; FP: false-positive; HI: high intensity; IR: intervention and resolution; M: male; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging; mRS: modified Rankin Scale; NA: not applicable; NC: no change; OP: occipital pain; P&S: pearl and strings sign; p.neck pain: posterior neck pain; SR: spontaneous resolution; TTH: tension type headache; VAD: vertebral artery dissection

*Occlusion and healing.

†At 13 months: contralateral internal carotid artery dissection (C5 segment).

‡6 After 31 months: fusiform dilatation expanded, stenting.

§At 1 month: VA occlusion, medullocerebellar infarct, stenting.

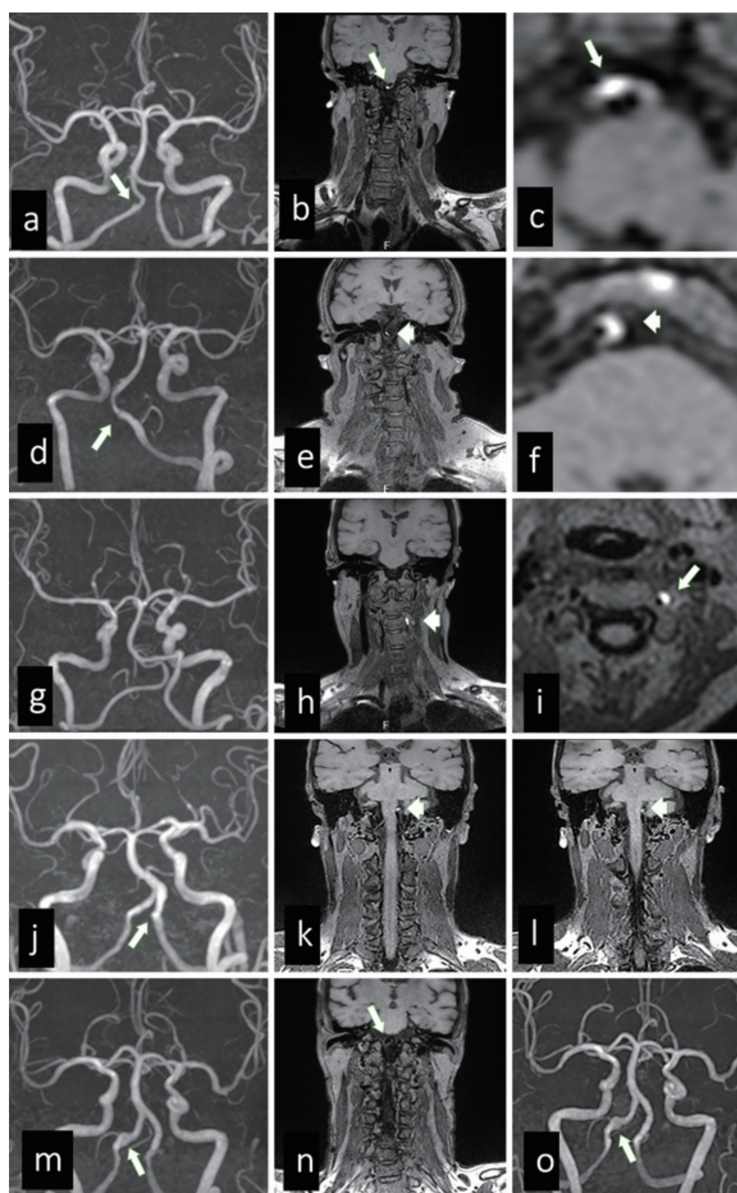

Figure 1 Representative cases of intracranial and extracranial mild vertebral artery dissection and false-positive cases.
Case 26 (Table 3): A 40-year-old man presented with bilateral occipital pain. MRA shows the right vertebral artery with barely discernible dilatation at the intracranial V4 segment (a), 3D T1-weighted BB MRI shows a small high intensity dot (b), and a reconstructed axial image of BB MRI shows a characteristic crescent sign (c).
Case 24 (Table 3): A 50-year-old man presented with left occipital pain. MRA shows slight stenosis of the left vertebral artery at the intracranial V4 segment (d). BB MRI shows a small high-intensity dot (e). The reconstructed axial image of the BB MRI shows a characteristic crescent sign (f).
Case 30 (Table 3): A 40-year-old woman presented with left eye and ear pain. MRA shows no vascular abnormalities (g), BB MRI shows a small high-intensity dot at the extracranial V2 segment (h), reconstructed axial image of BB MRI shows a characteristic crescent sign (i).
In all three cases, both clinical symptoms and imaging findings had completely disappeared at follow-up.
Case 33 (Table 3): A 63-year-old man presented with bilateral occipital pain. MRA shows slight dilatation of the left vertebral artery at the intracranial V4 segment (j), BB MRI shows small high-intensity dots (k), but no morphological change after 8 months (l), diagnosed as a false-positive case.
Case 37 (Table 3): A 73-year-old man presented with head heaviness. MRA shows fusiform dilatation of the right vertebral artery at the intracranial V4 segment (m). BB MRI shows no high-intensity signal (n), no morphological change after 12 months (o), diagnosed as a false-positive case.
3D: 3-dimensional; BB: black-blood; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

Table 4 Multivariate Logistic Regression Analysis for Predictors of Mild Vertebral Artery Dissection

Factors	Odds ratio	p-Value	95% CI
BB MRI	3.33	0.003	1.50-8.41
Sex (male vs female)	0.94	0.87	0.44-1.93
Age: 40-55 years	2.46	0.015	1.19-5.38
Occipital or posterior neck pain	15.8	<0.001	5.56-66.44
Hypertension	0.53	0.22	0.15-1.42
Hyperlipidemia	0.62	0.51	0.10-2.19

BB: black-blood; CI: confidence interval; MRI: magnetic resonance imaging

Discussion

Herein, we assessed whether adding brain and neck 3D T1-weighted BB MRI to standard brain MRI/MRA improves the detection of mild VAD in patients presenting with headache in a real-world setting. The key findings show that BB imaging increased mild VAD detection from 0.5% to 1.6%, with most intracranial mild VADs located in the V4 segment and a high prevalence of occipital headache among these cases. The analysis also suggests a substantially higher estimated incidence of mild VAD in this Japanese headache population and identifies a high-risk subgroup (ages 40-55 years with occipital or posterior neck pain) in which BB screening yielded a 7.5% detection rate. These results support the utility of BB imaging as an initial screening tool in high-risk patients presenting with headache and highlight its potential to uncover a larger burden of mild VAD than previously appreciated.

In Western countries, the incidence of cervical artery dissection is reported to be slightly higher for CAD than for VAD, with a CAD: VAD ratio of approximately 2.4:2.0.[6] In contrast, VAD is reported to be more common in Asian populations;[7,8] however, its true incidence and distribution in Japan, particularly for mild cases, remain unclear. This study demonstrated that VAD is highly prevalent in people presenting with mild symptoms, specifically headache.

The implementation of the noninvasive testing method, BB MRI, has allowed for mild VAD detection at a rate more than 3 times higher than that achieved with conventional MRA alone.

Incidence of VAD and CAD

A previous national epidemiological study reported an annual incidence of headache of approximately 1.1%.[2] In the present study, the mild VAD detection rate in the MRI+MRA+BB group was 1.6%. Based on these values, a highly conjectural preliminary estimate of the incidence of mild VAD in Japan was calculated as 17.6 per 100,000 individuals (calculated as 0.011 × 0.016 × 100,000).

CAD was reported in only 2 patients in the MRI+MRA+BB group, one of whom was Caucasian. The estimated incidence of CAD was approximately 1.5 per 100,000 individuals.

In 2001, the reported incidence of VAD in Western countries was 1 to 2 per 100,000 individuals.[3] Griffin et al.[6] later reported a fourfold increase in VAD detection between 2017 and 2020 due to improved diagnostic techniques, revising the incidence to approximately 5.3 per 100,000 individuals. In the present study, the estimated incidence of mild VAD in Japan was 17.6 per 100,000 individuals—more than threefold higher than recent Western estimates and approximately tenfold higher than that reported in 2001.

When applying a different calculation method based on the Patient Survey (October 2023), the estimated number of new outpatient visits in Japan for migraine (G43) and other headache syndromes (G44) was 4,000 per day (Ministry of Health, Labour and Welfare, Patient Survey 2023, Table 16-1).[19]

When adjusted for the total Japanese population of 123.8 million, the incidence of mild VAD is calculated as follows:

$$4{,}000 \times 0.016 \times 365\ \textit{days} \times \frac{100{,}000}{\textit{total Japanese population of}\ 123{,}800{,}000} = 18.9/100{,}000.$$

This figure is consistent with the incidence of mild VAD mentioned above (17.6 per 100,000 individuals).

For comparison, the incidence of subarachnoid hemorrhage, a life-threatening condition, is widely reported to be approximately 10 per 100,000 individuals. It would be unreasonable to assume that the incidence of unruptured mild VAD—characterized by mildly damaged vascular intima that often spontaneously heals with conservative therapy—is only one-tenth of that of subarachnoid hemorrhage. Despite pathological differences, a higher incidence of mild VAD compared to that of subarachnoid hemorrhage appears reasonable. Table 5 provides a literature-based comparison. Our hospital data include walk-in patients with mild VAD who presented solely with headache. We assume that our data are affected by racial differences, regional differences, improved diagnostic accuracy, and differences in patient populations.

Table 5 Literature Comparison of VAD Incidence Between the Present Study and Previous Reports

Author	Country	Study period	Methods of analysis	Target patients with VAD	Estimated VAD incidence
Lee et al. (5)	USA	1987-2003	DSA centered era	mainly moderate-severe cases	1.0/100,000
Griffin et al. (6)	USA	2017-2020	DSA, CTA, MRA	mainly moderate-severe cases	5.3/100,000
Present study	Japan	2021-2023	MRA+BB only	mild VADs; walk-in with only headache	17.6-18.9/100,000

BB: black-blood MRI; CTA, computed tomography angiography; DSA, digital subtraction angiography; MRA: magnetic resonance angiography; VAD, vertebral artery dissection

In contrast, the estimated incidence of CAD was 1.5 per 100,000 individuals, consistent with prior reports. These findings suggest that mild VAD is significantly more common, atypical, and clinically relevant in Japan.

Furthermore, the incidence of mild VAD among patients aged 40-55 years who reported occipital or posterior cervical pain reached 7.5%, corresponding to approximately one in 13 patients. Additionally, occipital pain, rather than nonspecific or generalized headache, emerged as a key clinical sign. Some patients specifically identified pain in the lower occipital region.

Diagnostic utility of BB MRI

BB MRI has proven useful not only in evaluating carotid plaques but also for diagnosing DVT and arterial dissections.[14,20] In cases of dissection, the high signal intensity on BB MRI is believed to represent thrombus formation within the false lumen. Although ultrasound is effective for evaluating carotid plaques and DVT, it is not applicable to intracranial VAD due to anatomical constraints.[21,22] D-dimer, a biomarker for thrombus formation, is useful for screening DVT and aortic dissection but is less effective for VAD due to the typically small thrombus volume.[23] Because CTA relies on contrast agents and digital subtraction angiography is significantly invasive and associated with procedural risks, these methods are generally not suitable for routine screening unless surgery is being considered.[17,24] In contrast, brain and neck BB MRI is noninvasive, does not require contrast agents, and has a short acquisition time of only 4.0 minutes. When combined with brain MRA, it significantly improves the detection rate of mild VAD. In clinical practice, as shown in Case 26 in Figure 1, BB MRI often revealed findings that were initially missed on brain MRA. The use of coronal imaging reduced acquisition time and slice count compared with axial imaging and allowed for the detection of extracranial VAD, which may otherwise have been overlooked.

MRA remains the first-line modality for the morphological diagnosis of intracranial VAD. In diagnostically challenging cases, we consider that adding BB MRI achieves ≥96% diagnostic accuracy.

If the most severe pathological state of VAD requiring medical interventions is likened to the peak of a mountain, then this screening modality may be considered to allow visualization of the foot of that mountain —the earliest stage of disease.

Prognosis

Mild VAD was observed in both sexes, indicating no sex-based difference in incidence. The condition predominantly affected individuals aged 40-55 years, a demographic critical to societal and familial roles, highlighting a notable public health concern. Accurate diagnosis is essential to guide management. Patients should be advised to rest, maintain blood pressure control, and be reassured that over 90% of cases resolve spontaneously without the need for surgical or other invasive interventions.

Limitations

This study has certain limitations. First, this was a retrospective, single-facility design, which may introduce selection bias and limit generalizability to other settings. Second, the study population was limited to Japanese patients with headache, which may reduce applicability to other ethnic groups and healthcare systems. Third, no hemorrhagic or ischemic-onset cases were included. This absence limits understanding of BB MRI performance in more severe presentations and may bias the perceived utility toward mild VAD. Fourth, in some instances, distinguishing VAD required further clinical and follow-up information due to overlap with other vascular conditions, limiting diagnostic certainty in real-world practice, and may lead to misclassification. Fifth, the lack of a formal, blinded, multi-reader adjudication process for the VAD diagnosis is a potential limitation that could introduce bias. Sixth, because of the limited number of mild VAD cases, multivariate analyses should be considered exploratory. Seventh, the estimation of VAD incidence involves extrapolation, and a population-based prospective study is required. These estimates are hypothesis-generating and dependent on several assumptions inherent to the study design.

Conclusions

The addition of BB MRI markedly increased the detection rate of mild VAD by more than threefold. BB MRI screening is effective for identifying high-risk patients presenting with headache. VAD accounted for the majority of head and neck arterial dissections. BB MRI screening results further indicated that VAD was frequently present in

patients with typical headaches.

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Conflicts of Interest Disclosure

All authors have no conflict of interest.

Data Availability Statement

Data supporting the findings of this study are available from the corresponding author.

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