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Case Report

Suspected Cerebral Hyperperfusion Syndrome after Stenting for Intracranial Vertebral Artery Stenosis Associated with Reduced Cerebral Blood Flow to the Posterior Cerebral Artery Territory

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Objective: Although several studies have reported on cerebral hyperperfusion syndrome (CHS)/hyperperfusion phenomenon (HPP) involving the anterior circulation after carotid artery stenting (CAS), little is known about CHS/HPP involving the posterior circulation after percutaneous transluminal angioplasty (PTA) and stenting of the vertebral artery (VA).
Case Presentation: A 79-year-old man with known chronic occlusion of the left VA (V4 segment) was admitted to another hospital with right-sided hemiplegia, mild disturbance of consciousness, and dysphagia. A head MRI revealed multiple infarcts in posterior circulation areas, and severe stenosis of the right VA (V4 segment). Single photon emission computed tomography (SPECT) indicated reduced cerebral blood flow (CBF) in the posterior circulation, and DSA revealed 76% stenosis of the right V4 segment. On day 18, PTA/stenting was performed under general anesthesia for the severe stenosis of the right VA. However, head MRI and CT on postoperative day (POD)1 showed intracranial hemorrhage (ICH) occupying an area measuring 2 cm in diameter in the left posterior lobe and a small subdural hematoma (SDH). SPECT on POD1 indicated increased CBF in the posterior lobe, and we diagnosed CHS might have caused ICH. Although SPECT on POD4 showed residual hyperperfusion, SPECT on POD11 revealed reduced CBF in the posterior circulation area.
Conclusion: Our patient developed ICH after undergoing PTA/stenting for known severe symptomatic stenosis of the right VA. CHS/HPP in the posterior cerebral artery territory might be one of the etiologies, and reduced CBF prior to the procedure could be a risk factor for CHS/HPP developing after PTA/stenting.

Keywords ▶ cerebral hyperperfusion syndrome, single photon emission computed tomography, stenting, posterior circulation

Introduction

Cerebral hyperperfusion syndrome (CHS)/hyperperfusion phenomenon (HPP) in the anterior circulation after carotid artery stenting (CAS) or carotid endarterectomy (CEA) is a well-recognized phenomenon.[1,2] Excessively rapid increase in the cerebral blood flow (CBF) under the state of dysautoregulation of the cerebral arteries due to severe carotid stenosis might lead to a sudden and dramatic increase in the cerebral perfusion pressure.[1] Preprocedural reduction of the CBF or cerebral vessel reaction (CVR) is commonly estimated as a predictor of CHS/HPP.[3,4] The commonly used diagnostic criteria for CHS in the anterior circulation are as follows: regional CBF (rCBF, ipsilateral/contralateral) increase >120%[5,6] or rCBF (postoperative/preoperative) >200%.[7]

Although there have been reports about CHS/HPP in the anterior circulation, little has been known about CHS/HPP in the posterior circulation. No information about CHS/HPP is mentioned in the report of the VIST trial,[8] and although intracranial hemorrhage (ICH)/subarachnoid hemorrhage (SAH) was observed in the stenting group in

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that trial, it remained uncertain if the hemorrhagic events were related to CHS/HPP.[9] Several case reports[10–17] about CHS/HPP in the posterior circulation after undergoing PTA/stenting for VA or subclavian artery and bypass surgery have been published; however, the risk factors and methods of prevention of CHS/HPP still remain unclear.

We report a case of ICH that might be caused by CHS developing after PTA/stenting for severe symptomatic right vertebral artery (VA) stenosis in a patient with known chronic occlusion of the left VA.

Case Presentation

A 79-year-old man with known chronic total occlusion of the left VA who was on treatment with clopidogrel was admitted to another hospital with right hemiplegia, mild disturbance of consciousness, and dysphagia. His National Institutes of Health (NIH) Stroke Scale score was 10 (right complete hemiplegia, mild disturbance of consciousness, and mild dysarthria). MRI on admission revealed multiple infarcts in the areas supplied by the left anterior inferior cerebellar artery (AICA) and right posterior cerebral artery (PCA), and the pons (**Fig. 1A–1C**). MRA (**Fig. 1D** and **1E**) indicated severe stenosis of the right VA (V4 segment) (newly diagnosed). Although the flow signal in the left distal PCA was poor, there was no infarction in the area supplied by the left PCA. The patient was additionally prescribed aspirin and was transported to our hospital on day 12 after treatment of aspiration pneumonia. On the day of admission, the patient developed acute transient loss of consciousness, bradycardia (heart rate 40/min), hypotension (blood pressure 70/30 mm Hg), with the loss of response to pain stimuli in both legs; however, all of these abnormalities disappeared within 10 minutes. Although head MRI revealed no new infarct, we considered the symptoms probably arose from vertebrobasilar insufficiency. DSA on day 17 (**Fig. 2A–2F**) revealed the following: the right vertebral angiography (VAG) revealed severe stenosis (Warfarin-Aspirin Symptomatic Intracranial Disease [WASID] method 76%),

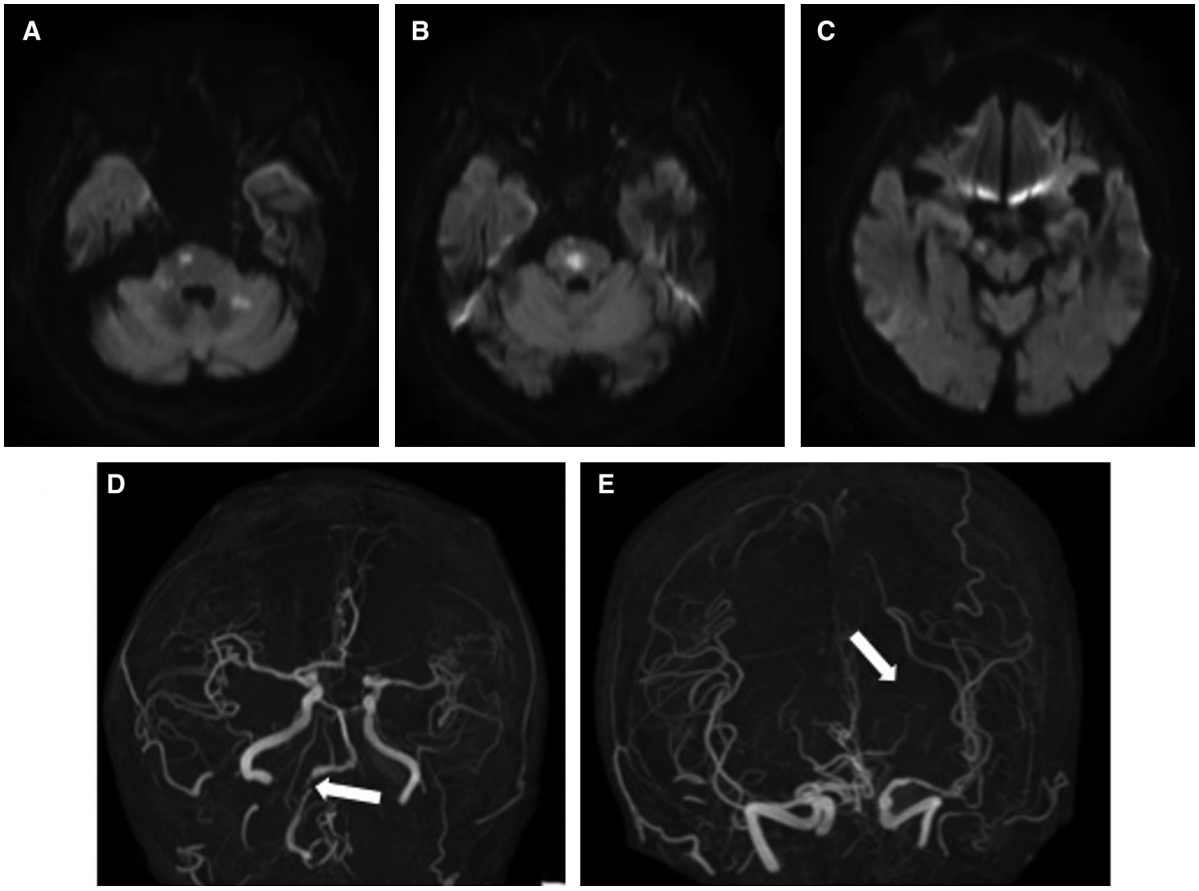

Fig. 1 MRI on admission revealed multiple infarcts in the posterior circulation area (**A–C**) and right VA stenosis (**D**, arrow). The visualization of the left PCA is poor (**E**). PCA: posterior cerebral artery; VA: vertebral artery

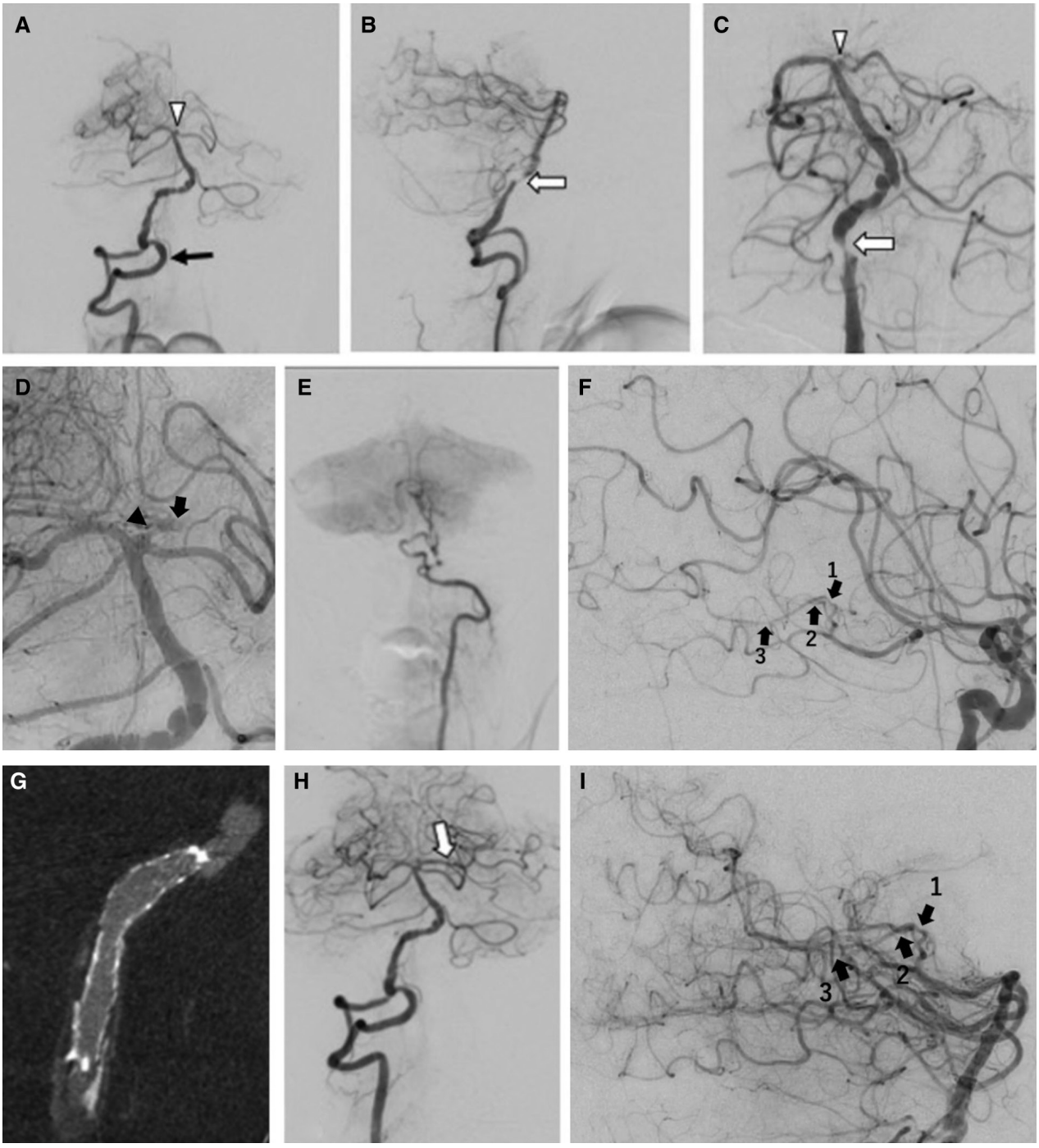

Fig. 2 Preoperative right VAG (**A–D**) revealed severe stenosis of the right VA (WASID 76%, white arrow) and duplication of the right VA (black arrow); the left PCA could not be visualized in the arterial phase (white arrowhead) and late phase of right VAG (**D**) revealed mild stenosis of left PCA (black arrowhead) and laminar flow without any embolus(black arrow). Left VAG (**E**) indicated distal occlusion of the VA and bilateral PICA-end. Left CCAG (**F**) revealed Pcom and left distal PCA with segmental stenosis (black arrows, 1–3). Intraoperative right VAG post PTA/stenting showed (**G**) residual stenosis (14%) and no evidence of in-stent thrombosis/stenosis. Postoperative right VAG of AP image (**H**) revealed antegrade flow into the left PCA with increased flow compared to preprocedural angiography (white arrow) and residual stenosis of PCA-P1 segment. Although postoperative right VAG of lateral image (**I**) revealed partial improvement of stenosis (black arrow, 2), residual distal PCA stenosis persisted (black arrows, 1 and 3). AP: anterior–posterior; CCAG: common carotid angiography; PCA: posterior cerebral artery; PICA: posterior inferior cerebellar artery; PTA: percutaneous transluminal angioplasty; VA: vertebral artery; VAG: vertebral angiography; WASID: Warfarin-Aspirin Symptomatic Intracranial Disease

duplication of the intracranial VA, and no perforator or anterior spinal artery near the stenotic segment. Right VAG also revealed mild stenosis of left P1, laminar flow without any embolus in left PCA, and distal left PCA was not visible antegradely. Left common carotid angiography (CCAG) revealed that left PCA territory was mainly perfused through left Pcom and PCA with distal stenosis, not through leptomeningeal anastomosis from left MCA. Left VAG revealed bilateral posterior inferior cerebellar artery (PICA)-end. And the patient also had a severely curved femoral artery. We considered the high risk of fatality and planned PTA/stenting under general anesthesia on day 18.

A 6Fr FUBUKI guiding sheath (ASAHI INTECC, Aichi, Japan) was inserted into the right femoral artery, and a long 4Fr sheath was inserted into the right radial artery. A gooseneck snare wire 7 mm (Medtronic, Minneapolis, MN, USA) was guided through radial sheath and caught the FUBUKI guiding sheath in the right innominate artery to stabilize the FUBUKI during the procedure. A 6Fr Cerulean DD6 catheter (MEDIKIT CO, Tokyo, Japan) was guided through the guiding sheath into the V2 segment of the right VA. A Gateway balloon catheter 3 mm × 12 mm (Stryker, Kalamazoo, MI, USA) was guided to the stenotic segment and PTA was performed (6 atm). However, elastic recoil was observed and we considered that stenting was necessary to counter the VA stenosis. A Wingspan stent 3.5 mm × 20 mm (Stryker) was guided through the CHIKAI wire (Asahi Intecc) and deployed, and cone-beam CT with diluted contrast agent revealed good apposition, without any plaque protrusion or thrombus, and indicated successful deployment (**Fig. 2G**).The left PCA was visible antegradely on the right VAG after the procedure clearly compared to preprocedural left PCA through Pcom (**Fig. 2H**). Postprocedural right VAG also revealed residual stenosis of distal left PCA as with preprocedural angiography (**Fig. 2I**). After awaking from general anesthesia, the patient exhibited no new neurological symptoms.

However, MRI on postoperative day (POD)1 revealed ICH occupying an area measuring 2 cm in diameter in the left posterior lobe, with a small subdural hematoma (SDH) (**Fig. 3A–3C**). No new infarction was detected in the left posterior lobe, and we confirmed that there had been no intraprocedural wire or catheter approach into the left PCA. Although preoperative single photon emission computed tomography (SPECT) on day16 (^{123}I-IMP, rest) indicated reduction of CBF in the posterior circulation areas, especially the PCA bilaterally (left dominant; **Fig. 3D**), SPECT (IMP, rest) on POD1 revealed increased CBF in the posterior circulation areas, including the posterior lobes, thalami, pons, and bilateral cerebellum (**Fig. 3E**). We performed intensive blood pressure lowering, desisted from using any sedatives and continued antithrombotic therapy, because the symptoms were mild. The CBF in the right PCA decreased on POD4 as compared to that on POD1, and the CBF in the thalami bilaterally and the right PCA decreased on POD11. We confirmed the threshold of each area was symmetrical bilaterally and calculated change of rCBF (**Fig. 3F**). No expansion of the hematoma on CT was detected during the clinical course, and MRI on POD34 revealed good flow in the stent and good posterior circulation.

The right hemiplegia and dysphagia persisted (mRS4), and the patient was transferred to a rehabilitation hospital.

Discussion

We encountered a case of ICH developing in left posterior lobe after PTA/stenting performed for symptomatic VA stenosis which might be caused by CHS/HPP. Generally, the diagnosis of CHS/HPP is determined by increasing more than >200% of CBF after procedure.[7] However, there are cases of ICH with focal drastic increasing of CBF, not completely met the criteria of increasing more than >200%.[18] Karapanayiotides et al. also found that perfusion-weighted imaging of patient with CHS/HPP after CEA indicated 20–44% relative interhemispheric difference of CBF to the contralateral side,[18] and some papers also define CHS/HPP after CAS as an asymmetry index more than 120% compared to contralateral side in the anterior circulation area.[5,6] However, since there are only a few case reports about CHS/HPP in the posterior circulation area,[10–17] no optimal cutoff data of the rCBF for diagnosis of CHS/HPP and the method of measurement or the cutoff data for rCBF are available in the posterior circulation area. Although our case did not meet the criteria of postprocedural increasing of CBF more than >200%, the rCBF in the right posterior lobe and bilateral thalami had increased by >120% compared to ipsilateral MCA territory, and pons and bilateral cerebellum also indicated increasing CBF after procedure. Although we could not determine the diagnosis, we considered that increasing of CBF in the posterior circulation area may be suggestive of CHS/HPP in the PCA territory. The other conceivable etiology of ICH after procedure is as follows: hypertensive,

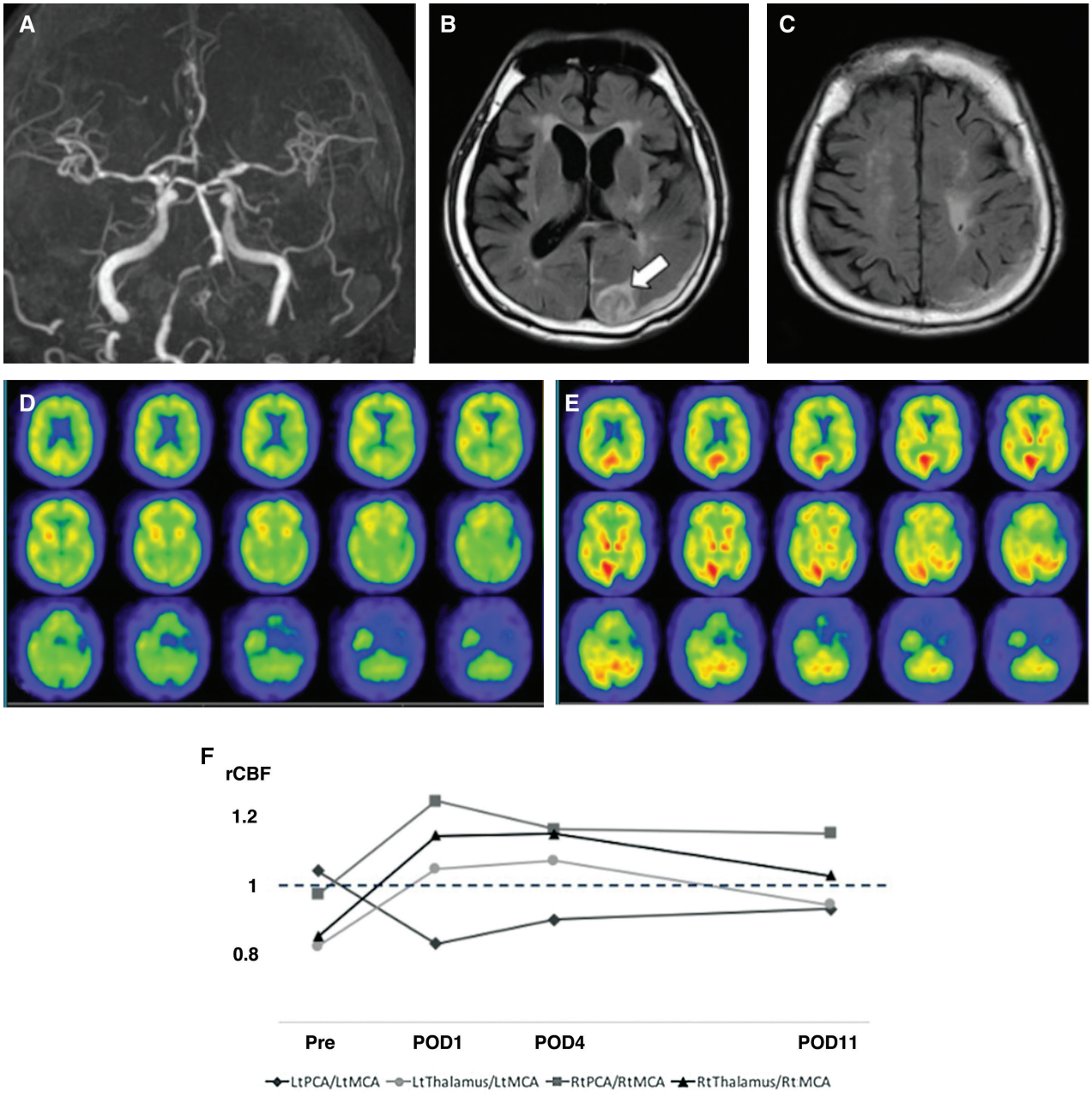

Fig. 3 MRI on POD1 revealed no specific flow abnormality of BA and proximal right VA (**A**) and intracranial hemorrhage in the left posterior lobe (**B, C**). Preoperative SPECT (**D**) revealed hypoperfusion of the posterior circulation. SPECT on POD1 indicated (**E**) hyperperfusion of the posterior circulation (right PCA territory, bilateral thalami, pons, and bilateral cerebellum), except for the area supplied by the left PCA, which showed hemorrhage. Evaluation of the rCBF and time passage (**F**) revealed a rapid and dramatic increase in the rCBF on POD1, with gradual reduction thereafter. BA: basilar artery; MCA: middle cerebral artery; Lt: left; PCA: posterior cerebral artery; POD: postoperative day; Rt: right; rCBF: regional cerebral blood flow; SPECT: single photon emission computed tomography; VA: vertebral artery

amyloid angiopathy, mechanical perforation, hemorrhagic infarction, and reperfusion injury after embolic stroke. Our patient did not reveal hypertension (systolic blood pressure >140mmHg) after the procedural course, and no microbleeds on MRI T2* imaging before procedure, indicating lower probability of hypertensive and amyloid-angiopathy-related ICH. We had not performed any wire or catheter approach of the left PCA, suggestive no chance of mechanical perforation. We also confirmed that there was no infarction of the left PCA territory before or after the

Table 1 PTA/stenting for atherosclerotic VA stenosis at our hospital

Age	M/F	Contralateral VA	Symptom	SPECT	Procedure	WASID	CHS
80	M	Collateral from DCA	Dizziness, nausea	None	PTA Stenting	76% →6%	(–)
54	M	Hypoplastic	Dizziness	None	PTA Stenting	80% →48%	(–)
81	M	Collateral from DCA	None	None	Stenting	70% →25%	(–)
54	F	Near occlusion	None	CBF normal	PTA Stenting	78% →4%	(–)
79	M	Occlusion	Hemiplegia	CBF reduced	PTA Stenting	76% →14%	(+)

CBF: cerebral blood flow; CHS: cerebral hyperperfusion syndrome; DCA: deep cervical artery; F: female; M: male; PTA: percutaneous transluminal angioplasty; SPECT: single photon emission computed tomography; VA: vertebral artery; WASID: warfarin aspirin symptomatic intracranial disease method

procedure, indicating that hemorrhagic infarction after the procedure was unlikely as the cause of the hemorrhage. Although left PCA on DSA after the procedure revealed no occlusion or emboli, existence of embolic source in left PCA, and reperfusion injury after recanalization of left PCA could not be completely denied. Therefore, we considered that CHS might be one of the compatible etiologies of ICH in our case.

We wish to highlight two important findings in our case. First, the reduced rCBF or total occlusion of the contralateral VA prior to the procedure probably contributed to the development of CHS/HPP in the PCA territory. In all case reports of CHS/HPP in the posterior circulation published to date, severe bilateral stenosis/occlusion of the VA or agenesis of the contralateral VA (PICA-end) was observed,[10–17] although the CBF was evaluated by SPECT in only three cases, including our case,[10–15] and in all, SPECT revealed preoperative hypoperfusion in the posterior circulation. In addition, we reviewed past cases of PTA/stenting for VA stenosis at our hospital and found that CHS/HPP in the presence of contralateral VA occlusion was diagnosed only in our case reported here (**Table 1**). The preoperative SPECT performed in the other of the two cases, who did not develop CHS/HPP, showed no preoperative hypoperfusion. Similar to cases of anterior circulation, we consider that chronic reduction of CBF and dysautoregulation of cerebral vessels, with the dramatic increase of the CPP after PTA/stenting could be associated with the development of CHS/HPP in the PCA territory. In our case, the CBF was reduced to a greater degree in the left posterior lobe than in the right posterior lobe, perhaps due to the site of the stenosis in the distal PCA and left P1 segment. Thus, we consider that the left posterior lobe was at a much higher risk of showing CHS/HPP than the right posterior lobe. Although stenotic site was observed after the procedure, postprocedural flow of left PCA increased angiographically compared to preprocedural PCA observed through Pcom from left ICA. Second, we could evaluate time course of changes of the CBF in the regions affected by CHS/HPP by SPECT. According to one report, the time peak of CHS after CAS was 12 hours,[19] quite early in the postoperative course. In our case, head MRI on POD1 revealed ICH in the posterior lobe and SPECT on POD1 revealed hyperperfusion in the PCA territory, and the time course of the CHS/HPP was similar to that in cases of CAS. One report revealed that the mean blood velocity in the MCA as measured by Transcranial Doppler sonography (TCD) was elevated 2–5 days in cases of CHS/HPP developing after CAS.[20] However, there are no other reports of the time course of changes in the CBF as measured by SPECT or velocity as measured by TCD, and the duration of persistence of CHS/HPP in the posterior circulation area after intervention for the VA remains uncertain. In our case, SPECT on POD1 and POD4 indicated increased CBF, while that on POD11 revealed a decrease in the rCBF in all the posterior circulation area. We consider that CHS/HPP in the PCA territory might progress for at least 1–4 days after the procedure, and intensive observation is necessary.

Conclusion

We have reported a case of ICH after PTA/stenting for severe symptomatic stenosis of the right VA in a patient with known chronic occlusion of the left VA. Although there are no optimal method of measurement and cutoff data of the rCBF for diagnosis of CHS/HPP are available in the posterior circulation area, our case indicated increasing in rCBF in the posterior lobe, and we suggest CHS/HPP in the PCA territory might be one of the etiologies of ICH. We consider that reduced rCBF prior to the procedure might be a risk factor for the development of CHS/HPP after PTA/stenting of the VA.

Disclosure Statement

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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