Online August 28, 2020
Journal of Neuroendovascular Therapy 2021; 15: 38–45
DOI: 10.5797/jnet.cr.2020-0015

Case Report

A Patient with Moyamoya Disease Who Underwent Recanalization Therapy for Acute Intracranial Internal Carotid Artery Occlusion

Shu Sogabe,[1] Yasuhisa Kanematsu,[1] Takeshi Miyamoto,[1] Izumi Yamaguchi,[1] Yuki Yamamoto,[2] Tadashi Yamaguchi,[1] Nobuaki Yamamoto,[2] Kenji Shimada,[1] and Yasushi Takagi[1]

Objective: We report a case of acute internal carotid artery occlusion in a patient with adult-onset moyamoya disease who underwent mechanical thrombectomy and had a good outcome.

Case Presentation: A 73-year-old woman was diagnosed with moyamoya disease by asymptomatic right middle cerebral artery occlusion at 59 years of age. The patient was transported for stroke symptoms. Magnetic resonance imaging (MRI) demonstrated left terminal internal carotid artery occlusion and low-intensity signal on T2*-weighted imaging at the occlusion site. Alteplase was administered and endovascular treatment was subsequently performed. A small-diameter microcatheter was guided to the distal end of the occlusion and angiography after deployment of a stent retriever revealed irregular stenosis. Severe stenosis remained after thrombectomy, and balloon angioplasty was added. The treatment resulted in recanalization and good outcome.

Conclusion: Adults with moyamoya disease may have accompanying atherosclerotic intracranial artery occlusion. Angiography after deployment of a stent retriever was useful for clarifying the etiology of occlusion. It is important to determine the etiology of occlusion based on the medical history or imaging findings and to select an appropriate treatment.

Keywords ▶ moyamoya disease, acute recanalization therapy, percutaneous intracranial thrombectomy, percutaneous intracranial angioplasty

Introduction

Moyamoya disease (spontaneous occlusion of the circle of Willis, cerebrovascular "moyamoya" disease) is a condition in which collaterals via abnormal net-like vessels develop in the base of the brain in the course of chronic progressive stenosis of the bilateral terminal internal carotid arteries. The diagnosis is made by morphological evaluation (stenosis/occlusion is demonstrated by cerebral angiography in the area centering around the terminal internal carotid artery with abnormal net-like vessels in the neighborhood) and exclusion (conditions associated with arterial sclerosis, such as autoimmune disease, meningitis, neurofibromatosis type 1, cerebral tumor, and Down syndrome, are excluded).[1)] For patients who have disease onset with ischemia, direct vascular reconstruction is recommended in the chronic phase.[1)]

The percentage of patients with moyamoya disease aged 50 years and above is increasing recently,[1)] and the number of patients with moyamoya disease complicated by cardioembolic stroke and acute atherosclerotic large artery occlusion is expected to increase. Although treatment in the acute phase of occlusive lesions due to moyamoya disease is difficult, if cardioembolic stroke and atherosclerotic acute occlusion can be diagnosed, the functional prognosis may be improved by acute phase recanalization therapy.

We report a patient with adult-onset moyamoya disease for whom a favorable outcome was achieved by acute phase recanalization therapy for acute internal carotid artery occlusion.

[1]*Department of Neurosurgery, Graduate School of Biomedical Sciences, Tokushima University, Tokushima, Tokushima, Japan*
[2]*Department of Clinical Neurosciences, Graduate School of Biomedical Sciences, Tokushima University, Tokushima, Tokushima, Japan*

Received: January 26, 2020; Accepted: June 20, 2020
Corresponding author: Shu Sogabe. Department of Neurosurgery, Graduate School of Biomedical Sciences, Tokushima University, 3-18-15, Kuramotocho, Tokushima, Tokushima 770-8503, Japan
Email: c200001043@yahoo.co.jp

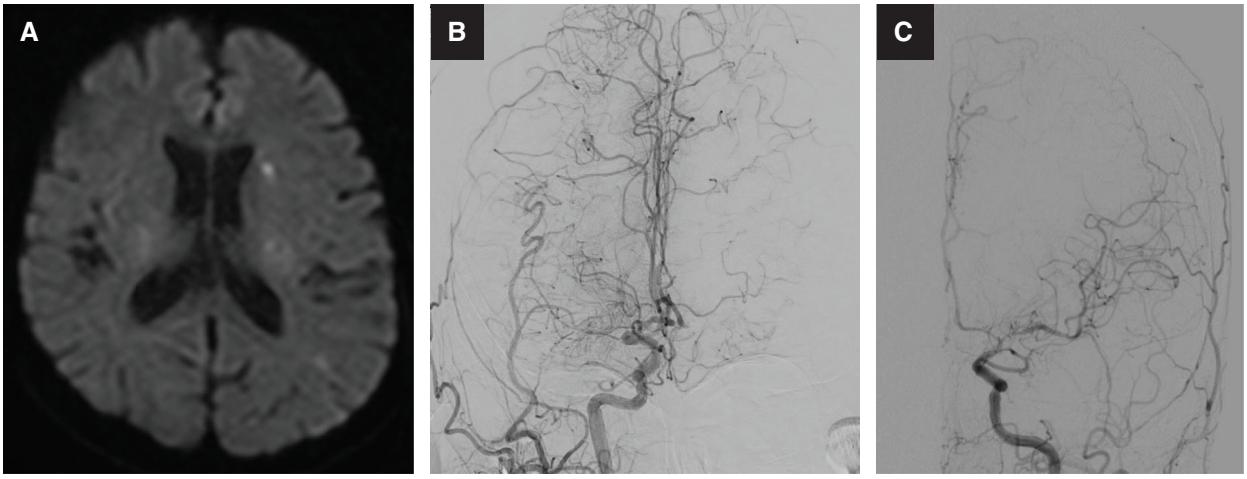

Fig. 1 (**A**) MRI DWI at the initial episode. High-intensity foci are observed in the left watershed region. (**B**) DSA of the right common carotid artery showing stenosis of the terminal right internal carotid artery, occlusion of the middle cerebral artery, and moyamoya vessels in the basal ganglia region. Well-developed anterior cerebral artery and collaterals are observed. (**C**) DSA of the left common carotid artery. Severe stenosis is observed from the terminal left internal carotid artery to the proximal middle cerebral artery. DSA: digital subtraction angiography; MRI DWI: magnetic resonance imaging diffusion-weighted imaging

Case Presentation

Patient: A 73-year-old woman

Primary symptoms: Acute right hemiplegia, dysarthria, and aphasia

Life history: No smoking or drinking habit

Past history: Right middle cerebral artery occlusion was detected by brain check-up 14 years ago.

Drug therapy for hypertension was initiated 5 years ago. Transient ischemic attack was observed 1 year ago. In addition to cerebral infarction of the left watershed region (**Fig. 1A**) and proximal right middle cerebral artery occlusion, severe stenosis was observed in the terminal left internal carotid artery. Digital subtraction angiography (DSA) was performed, revealing occlusion of the proximal right middle cerebral artery and stenosis of the left internal carotid artery. Collaterals via the pial anastomoses of the anterior cerebral artery and abnormal net-like vessels in part of the basal ganglia were observed. Although the findings differed from the typical imaging characteristics of moyamoya disease, a diagnosis of moyamoya disease was made because the patient had an episode of asymptomatic right middle cerebral artery occlusion in her youth when she had no risk factors for moyamoya disease and she subsequently developed internal carotid artery stenosis (**Fig. 1B** and **1C**). According to the staging system proposed by Suzuki et al.,[2] the disease was diagnosed as stage 2–3 on the right side and stage 1–2 on the left side. Superficial temporal artery-middle cerebral artery bypass surgery was considered, but as the patient did not consent, internal treatment by cilostazol administration was selected.

History of present illness: At around 15:00, while the patient was exercising in a swimming pool, she became unable to get out of the pool by herself and an ambulance was called. The ambulance crew noted right hemiplegia and dysarthria. The patient was transported by helicopter and arrived at our hospital at 15:56.

Physical findings: Blood pressure: 198/102 mmHg, heart rate: 76 beats/min, sinus rhythm, and SpO2: 97% (room air)

Neurological findings: Lethargy with a Glasgow Coma Scale (GCS) score of E3V4M6, right facial nerve paralysis, dysarthria, right hemiplegia, primarily motor aphasia, and National Institutes of Health Stroke Scale (NIHSS) score of 6/42

Neuroradiology findings: 3T-magnetic resonance diffusion-weighted imaging (DWI) demonstrated mild high-intensity foci in part of the left caudate nucleus, putamen, and corona radiate. On magnetic resonance angiography (MRA), the left terminal internal carotid artery was occluded (**Fig. 2A** and **2B**). Findings suggestive of thrombus were noted at the site of occlusion on T2*WI (**Fig. 2C**).

Blood test findings: Total cholesterol: 213 mg/dL, triglycerides: 175 mg/dL, high-density lipoprotein (HDL) cholesterol: 77 mg/dL, low-density lipoprotein (LDL) cholesterol: 119 mg/dL, blood sugar level: 127 mg/dL, and HbA1c (NGSP): 6.3%

Clinical course: We judged there to be a mismatch between the left middle cerebral artery territory and DWI lesion. Although the guidelines for intravenous alteplase therapy recommend careful administration for moyamoya disease

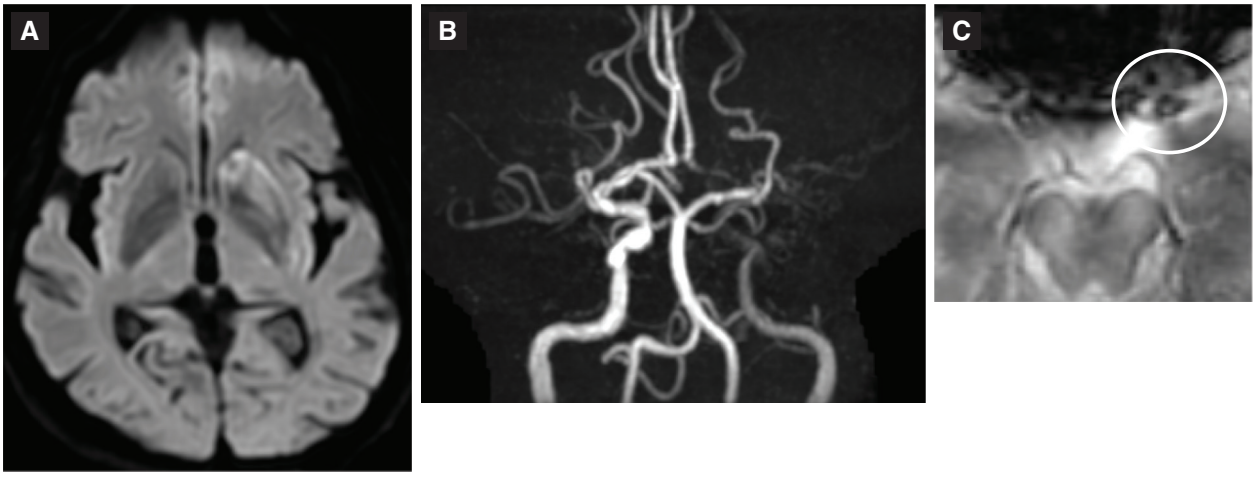

Fig. 2 (**A**) MRI DWI at the present episode. Mild high-intensity foci are observed in the left caudate nucleus and putamen. (**B**) MRA showing occlusion of the terminal left internal carotid artery. (**C**) T2*WI showing low-intensity foci considered a SVS in the terminal left internal carotid artery (white circle). MRA: magnetic resonance angiography; MRI DWI: magnetic resonance imaging diffusion-weighted imaging; SVS: susceptibility vessel sign

and during antithrombotic treatment, there were no relevant contraindications. Alteplase administration was started at 17:19. The symptoms were improved to mild dysarthria alone (NIHSS 1/42) 30 minutes after starting alteplase administration. However, the condition was exacerbated again after 19:00 with the development of reduced consciousness, severe paralysis of the right upper and lower extremities, motor aphasia, and dysarthria (NIHSS 17/42). No hemorrhage was noted on computed tomography (CT) of the head, and the findings were considered to be due to exacerbation of ischemic symptoms. As alteplase administration temporarily improved the symptoms, the condition was judged to be an indication of endovascular recanalization therapy and angiography was performed.

Endovascular treatment: A 5-Fr sheath was placed in the right femoral artery, and bilateral common carotid artery and left vertebral artery angiography was performed (**Fig. 3A–3C**). The development of collaterals via the pial anastomoses from the anterior cerebral and posterior cerebral arteries and the external carotid artery system was observed. Concerning occlusion of the left internal carotid artery, a large vessel was abruptly terminated, leaving the stump, and a crab claw-like filling defect, which indicated thrombus, was also noted (**Fig. 3D**). The findings suggested an acute phase change rather than a chronic change of moyamoya disease.

The 5-Fr sheath was replaced with a 9-Fr sheath, and a 9-Fr OPTIMO (Tokai Medical Products, Aichi, Japan) was navigated to the left internal carotid artery. An Excelsior SL-10 (Stryker, Kalamazoo, MI, USA) was guided through a CHIKAI 14 200 cm (Asahi Intecc, Aichi, Japan) to the distal side of occlusion, and the distal vessel was secured. On angiography through the microcatheter, the distal part of the vessel remained relatively normal (**Fig. 4A**) and internal carotid artery occlusion was suspected to be thrombotic. We decided to assess the shape of occlusion by deploying a Tron FX 4.0*20mm (JIMRO, Gunma, Japan) to decide which procedure to perform. When the Tron was deployed, immediate flow restoration was noted, but the vascular wall was irregular and atherothrombotic embolism was suspected (**Fig. 4B**). The Tron was retrieved relatively easily and white matter was collected at its tip. Although angiography demonstrated recanalization, severe stenosis persisted (**Fig. 4C**). The vascular diameter was 2.6 mm on the proximal side of stenosis, 1.8 mm on the distal side, and 0.3 mm at the narrowest part. As the risk of reocclusion was considered high, we decided to perform additional balloon angioplasty. A stomach tube was inserted, and 300 mg of pulverized aspirin and 300 mg of clopidogrel were administered. Thereafter, a Gateway 2.0*12 mm OTW (Stryker) was guided to the site of stenosis using the CHIKAI. Gradual dilation and contraction were repeated two times at a nominal pressure from the distal to the proximal side of stenosis. After the procedure, angiography confirmed complete recanalization of the site of occlusion and satisfactory dilatation of the stenosed area (**Fig. 4D**). Angiography was performed again after 20 minutes, and as there was no sign of reocclusion, the operation was ended.

The recovered material consisted of red blood cells, neutrophils, and fibrin, and was a relatively new thrombus exhibiting no organization (**Fig. 4E**).

Postoperative course: The condition improved to NIHSS 5 on the day after surgery. The administration of aspirin at 100 mg

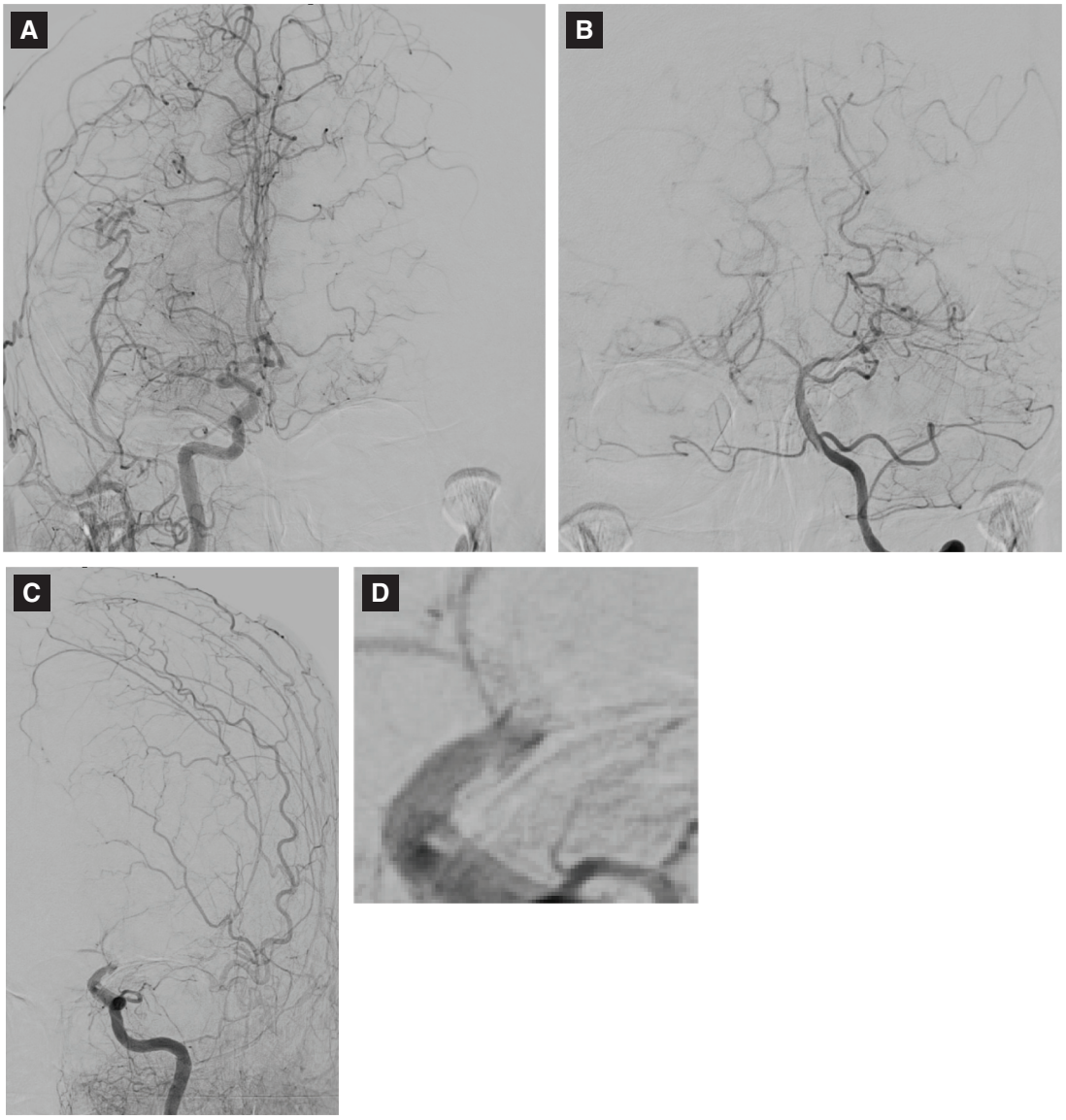

Fig. 3 Angiography. (**A**) Right common carotid arteriography. The findings are nearly identical to those of previous angiography. (**B**) Left vertebral arteriography showing left-side-dominant development of the posterior cerebral artery and collaterals. (**C**) Left common carotid arteriography showing occlusion of the terminal internal carotid artery and development of the external carotid artery. (**D**) An enlarged view of the terminal internal carotid artery. Interruption of the blood flow and filling defect suggestive of thrombus are observed.

and clopidogrel at 75 mg was continued after surgery. Magnetic resonance imaging (MRI) performed on the 14th hospital day revealed that the infarct area was limited and the left middle cerebral artery was clearly delineated (**Fig. 5A** and **5B**). On T2*WI, the low-intensity area at the site of occlusion disappeared (**Fig. 5C**). Concerning symptoms, only mild right hemiplegia remained and the patient was discharged to home with a modified Rankin scale score of 1 on the 17th hospital day. No recurrence of cerebral infarction was noted during a follow-up period of more than 3 months after surgery.

Discussion

Moyamoya disease is a disease of unknown etiology that causes chronic progressive stenosis or occlusion of the bilateral terminal internal carotid arteries. Stenosis is caused primarily by fibrous intimal thickening[3] and its pathological characteristics markedly differ from those of atherosclerotic intimal thickening. However, pathological findings are difficult to obtain by methods other than autopsy, and the diagnosis of moyamoya disease depends

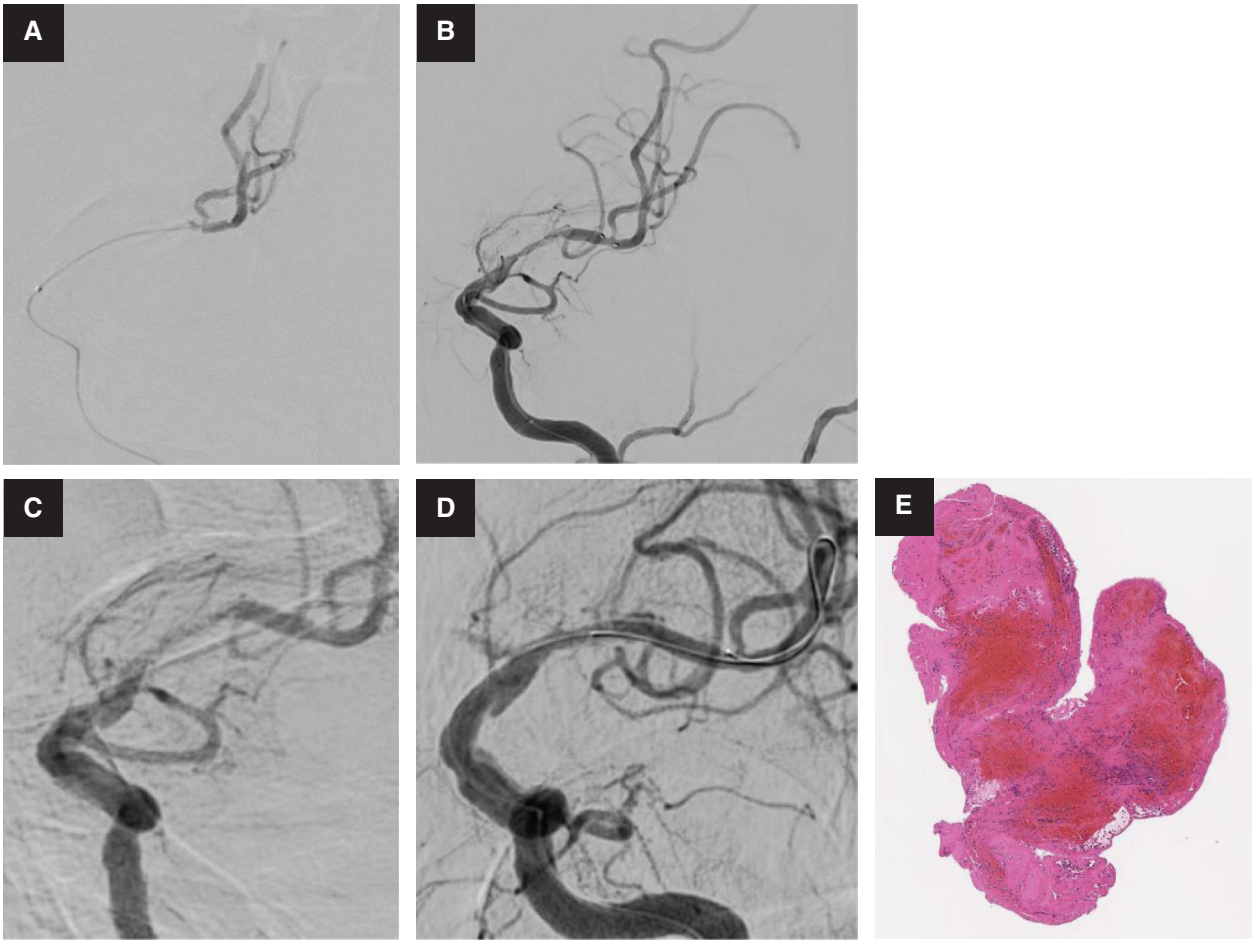

Fig. 4 Endovascular treatment. (**A**) Microcatheter angiography distal to the site of occlusion. The diameter of the peripheral vessel remains nearly normal. (**B**) After deployment of the Tron FX. Immediate flow restoration is observed. The vascular wall at the site of occlusion is irregular. (**C**) After retrieval of the Tron FX. Although the internal carotid artery was recanalized, findings of severe stenosis persisted. (**D**) After balloon angioplasty. The site of stenosis is dilated. (**E**) Retrieved thrombus. The thrombus consisted of red blood cells, neutrophils, and fibrin.

on morphological examination by cerebral angiography or MRI and exclusion of associated diseases. However, there is no clear definition of abnormal net-like vessels in the basal ganglia region, and the differential diagnosis of adult-onset moyamoya disease and atherosclerosis may be difficult and is presently made comprehensively.[1] Recently, p.R4810K mutation of the RNF213 gene was identified as a susceptibility factor[4] and is expected to be useful as an objective diagnostic index, but the percentage of its carriers relative to the prevalence of moyamoya disease is markedly high (0.5%–2% in East Asia), and only a small fraction of the carriers develop the disease.

The patient presented in this report was found to have asymptomatic right middle cerebral artery occlusion at the age of 59 years, when she had no risk factors for atherosclerosis, and exhibited stenosis of the terminal left internal carotid artery at the time of transient ischemic attack 1 year before when we comprehensively diagnosed moyamoya disease and considered internal carotid artery stenosis as a result of progression of moyamoya disease. However, as the patient had a 14-year history of moyamoya disease and developed hypertension during the course, it was considered necessary to suspect the involvement of atherosclerotic factors. Regarding autopsy findings, hypertensive change was also observed in the vertebrobasilar artery of patients with moyamoya disease.[2] Lee et al.[5] reported a patient with moyamoya disease who had a favorable outcome after stenting for external carotid artery stenosis and suggested that external carotid artery stenosis was likely to have been atherosclerotic change.

In the present patient, the disease was sudden-onset and followed a serious course. MRI demonstrated occlusion of the terminal left internal carotid artery, which was stenosed 1 year before. Progression of moyamoya disease was

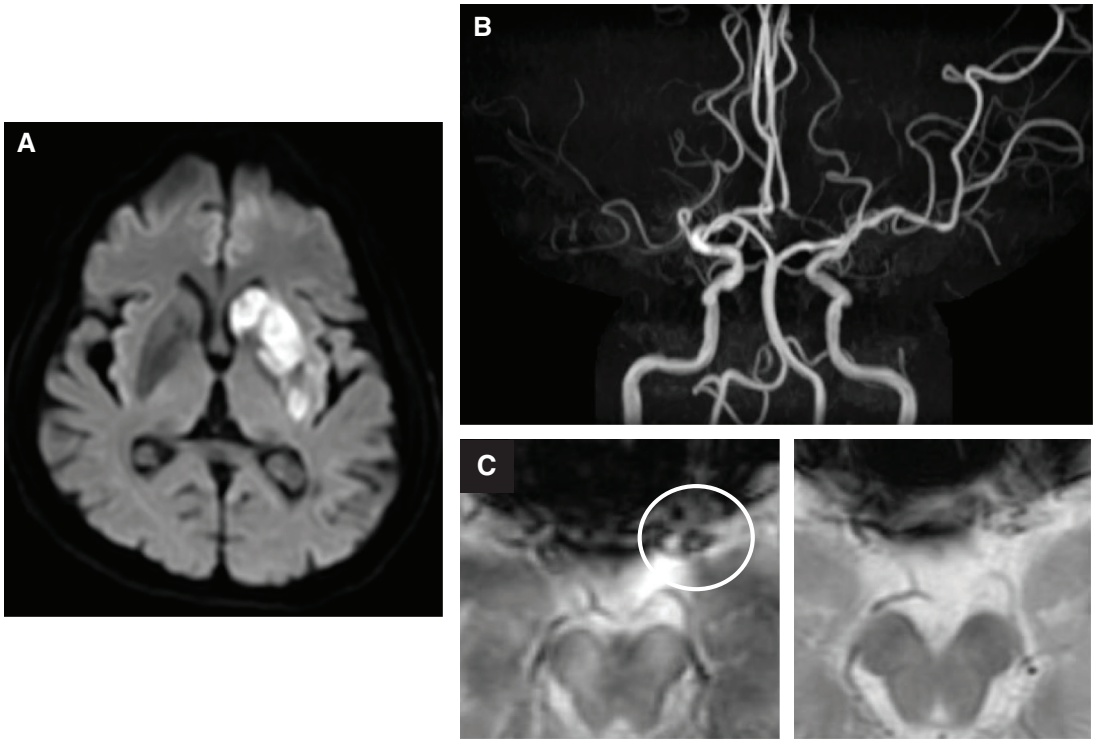

Fig. 5 (**A**) Postoperative MRI DWI. Clear high-intensity foci are observed in the basal ganglia region. (**B**) Postoperative MRA. Findings of recanalization of the left middle cerebral artery remain. (**C**) Preoperative (left) and postoperative (right) T2*WI. The low-intensity foci preoperatively observed at the occluded vessel disappeared after surgery. MRA: magnetic resonance angiography; MRI DWI: magnetic resonance imaging diffusion-weighted imaging

considered possible, but the low-intensity in the occluded vessel on T2*WI was considered a susceptibility vessel sign (SVS) suggestive of thrombus. MRI of 3T or higher was reported to delineate thrombus as SVS whether it is cardiogenic or atherosclerotic.[6] In the present case, we administered alteplase by assuming ultra-acute cerebral infarction, although precise evaluation of the condition was difficult on the arrival. There have been sporadic reports of low-dose (0.6 mg/kg) alteplase administration for moyamoya disease[7–9] and no hemorrhagic complications were noted. In our case, temporary symptomatic improvement was observed after alteplase administration. Vascular evaluation was impossible during this period, but the development of recanalization and reocclusion of the occluded vessel were suspected; therefore, thrombotic occlusion was considered to have been a greater etiological factor than the progression of moyamoya disease.

There are no established guidelines for surgical treatment in the acute phase of moyamoya disease. If progressive symptoms of ischemia or hemodynamic disturbance are observed in the acute phase, early direct vascular reconstruction was reported to be effective.[10,11] However, there is also a report that the incidence of perioperative ischemic complications is high in moyamoya disease with an unstable course exhibiting events such as rapid stenosis or occlusion of a major artery.[12]

Moreover, there are a number of negative reports about percutaneous angioplasty for moyamoya disease.[13–15] Gross et al.[15] reviewed 28 cases of endovascular treatments for moyamoya vessels in seven reports. According to this review, 7% had hemorrhagic complications, 11% did not have effective dilation, 53% eventually received surgical vascular reconstruction, and treatment by endovascular therapy alone was successful in only 25%. These results may have been due to pathological differences from atherosclerotic lesions.

The present patient resisted internal treatment and was considered to require additional treatments. In addition, the clinical course and MRI findings were not characteristic of the progression of moyamoya disease. Therefore, we performed angiography in consideration of the possibility of thrombotic etiology. As expected, angiographic findings were suggestive of thrombotic occlusion and the possibility of recanalization by endovascular treatment was considered high.

There are also no established guidelines for endovascular treatment for acute atheromatous occlusion of intracranial vessels, but Tsang et al.[16] reviewed 1967 cases of thrombectomy for intracranial large artery occlusion of any type in

11 reports. The review, in which atherosclerotic occlusion and cardioembolic stroke were compared retrospectively, revealed that additional angioplasty was more often required for atherosclerotic occlusion (46.8% vs. 3.9%), but that there was no significant difference in the final recanalization rate, incidence of symptomatic hemorrhage, or outcome. Among the thrombectomy procedures in the reviewed reports, a stent retriever was frequently used as the first choice. In the present case, as thrombectomy was performed while the diagnosis was unclear, evaluation was necessary for selection between the stent retriever and aspiration catheter. The stent retriever is advantageous in that it can immediately restore blood flow, visualize the lesion by imaging after deployment, and enable the diagnosis of embolic or atherothrombotic occlusion. On the other hand, it carries the risk of hemorrhage and dissection as it exerts direct stress on the luminal wall of the stenosed vessel. The aspiration catheter is advantageous in that recanalization can be attempted without direct mechanical contact with the lesion, but it is difficult to navigate to the lesion in stenosed vessels. In the present case, we first attempted to pass a thin catheter through the lesion and assess the condition of the peripheral vessels. As a result, we judged the lesion to be thrombotic occlusion and deployed a Tron, thereby enabling the procedure to be continued without interruption. As it resulted in temporary restoration of the blood flow and a diagnosis of atherothrombotic occlusion, subsequent angioplasty was possible.

The condition in the present patient was stage 1–2 moyamoya disease complicated by thrombotic occlusion, and endovascular treatment was effective. Narrowing of the outer diameter of the internal carotid and middle cerebral arteries was previously reported as a finding specific to moyamoya disease unobserved in atherosclerotic lesions.[17] The risk of endovascular treatment is considered to increase further if the blood vessels become more stenosed with the progression of moyamoya disease. In our patient, we judged the possibility of progression of narrowing of the blood vessel itself to be low based on the relatively recent angiographic findings and the images of peripheral vessels in the occluded area. In addition, we judged the lesion to be primarily thrombotic occlusion from the SVS in the occluded vessel on preoperative T2*WI and the crab claw-like filling defect on angiography, and were therefore able to carry out endovascular treatment with a relatively low risk. Evaluation of the outer diameter of blood vessels by high-resolution MRI, such as three-dimensional (3D) constructive interference in steady-state (CISS) MRI, reported by Kaku et al.[17] is considered promising for the risk assessment of endovascular treatment for moyamoya disease, although we did not employ it in this study.

We reported a patient with moyamoya disease who developed acute occlusion of a major artery and resisted internal treatment. We explored the possibility of treatment by evaluating the occlusion pattern from multiple viewpoints without completely relying on the patient history, which resulted in safe implementation of recanalization therapy and a favorable outcome. Older patients with moyamoya disease are expected to increase in the future. Examinations and treatments in consideration of the possibility of age-associated complications are considered necessary for older patients with moyamoya disease exhibiting acute symptoms.

Conclusion

Adult-onset moyamoya disease may be complicated by atherosclerotic lesions associated with aging and the progression of lifestyle-related diseases. For cerebral infarction due to large artery occlusion in adult-onset moyamoya disease, it is necessary to evaluate the disease state based on clinical history and imaging findings, and to select appropriate treatments.

Disclosure Statement

The authors declare no conflict of interest.

References

1) Tominaga T, Suzuki N, Miyamoto T, et al. Recommendations for the management of moyamoya disease: a statement from research committee on spontaneous occlusion of the circle of Willis (Moyamoya disease) [2nd edition]. *Surg Cereb Stroke* 2018; 46: 1–24. (in Japanese)
2) Suzuki J, Takaku A: Cerebrovascular "moyamoya" disease. Disease showing abnormal net-like vessels in base of brain. *Arch Neurol* 1969; 20: 288–299.
3) Hosoda Y, Ikeda E, Hirose S. Histopathological studies on spontaneous occlusion of the circle of Willis (cerebrovascular moyamoya disease). *Clin Neurol Neurosurg* 1997; 99 Suppl 2: S203–S208.
4) Liu W, Morito D, Takashima S, et al: Identification of RNF213 as a susceptibility gene for moyamoya disease and its possible role in vascular development. *PLoS ONE* 2011; 6: e22542.
5) Lee SJ, Ahn JY: Stenosis of the proximal external carotid artery in an adult with moyamoya disease: moyamoya or atherosclerotic change? *Neurol Med Chir (Tokyo)* 2007; 47: 356–359.

6) Yamamoto N, Satomi J, Yamamoto Y, et al: The susceptibility vessel sign containing two compositions on 3-tesla T2*-weighted image and single corticosubcortical infarct on diffusion-weighted image are associated with cardioembolic stroke. *J Neurol Sci* 2015; 359: 141–145.
7) Tabuchi S, Nakajima S, Suto Y, et al: Emergency superficial temporal artery to middle cerebral artery bypass after intravenous recombinant tissue plasminogen activator administration for acute cerebral ischemia in a patient with moyamoya disease. *Case Rep Neurol* 2013; 5: 214–219.
8) Yokoyama S, Manabe Y, Fujii D, et al: Intravenous tissue plasminogen activator therapy for an acute ischemic stroke patient with later diagnosed unilateral moyamoya syndrome. *J Stroke Cerebrovasc Dis* 2013; 22: 1190–1192.
9) Lee HM, Eun MY, Seo WK, et al: Thrombolysis for acute ischemic stroke in a patient with Moyamoya disease. *Can J Neurol Sci* 2012; 39: 687–689.
10) Kim SK, Seol HJ, Cho BK, et al: Moyamoya disease among young patients: its aggressive clinical course and the role of active surgical treatment. *Neurosurgery* 2004; 54: 840–844; discussion 844–846.
11) Yokosawa M, Hayashi T, Shirane R, et al: Efficacy of superficial temporal artery-middle cerebral artery double anastomoses in a patient with rapidly progressive moyamoya disease: case report. *Neurol Med Chir (Tokyo)* 2014; 54: 836–840.
12) Funaki T, Takahashi JC, Takagi Y, et al: Unstable moyamoya disease: clinical features and impact on perioperative ischemic complications. *J Neurosurg* 2015; 122: 400–407.
13) Natarajan SK, Karmon Y, Tawk RG, et al: Endovascular treatment of patients with intracranial stenosis with moyamoya-type collaterals. *J Neurointerv Surg* 2011; 3: 369–374.
14) Khan N, Dodd R, Marks MP, et al: Failure of primary percutaneous angioplasty and stenting in the prevention of ischemia in Moyamoya angiopathy. *Cerebrovasc Dis* 2011; 31: 147–153.
15) Gross BA, Thomas AJ, Frerichs KU: Endovascular treatment of symptomatic moyamoya. *Neurosurg Rev* 2014; 37: 579–583.
16) Tsang ACO, Orru E, Klostranec JM, et al: Thrombectomy Outcomes of Intracranial Atherosclerosis-Related Occlusions. *Stroke* 2019; 50: 1460–1466.
17) Kaku Y, Morioka M, Ohmori Y, et al: Outer-diameter narrowing of the internal carotid and middle cerebral arteries in moyamoya disease detected on 3D constructive interference in steady-state MR image: is arterial constrictive remodeling a major pathogenesis? *Acta Neurochir (Wien)* 2012; 154: 2151–2157.