

Surgical Management of Intracranial Artery Dissection

Koichi ARIMURA^{1,2} and Koji IIHARA²

¹*Department of Neurosurgery, Kobe City Medical Center General Hospital, Kobe, Hyogo;*

²*Department of Neurosurgery, Graduate School of Medical Sciences,
Kyushu University, Fukuoka, Fukuoka*

Abstract

Intracranial artery dissection (IAD) is a relatively rare cause of stroke, but it has been recognized increasingly with recent advances of the neuroimaging technique. Since rebleeding occurs frequently in the acute stage in the ruptured IAD, urgent surgical treatment should be performed to prevent rebleeding. On the other hand, surgical treatment for unruptured IAD is controversial because it has little risk for bleeding. However, surgical treatment for unruptured IAD may be considered if the formation or enlargement of the aneurysmal dilatation has been confirmed. Since there are several proposed surgical strategies for IAD, it is important to select an appropriate strategy on a case-by-case basis. If the risk of infarction due to vessel occlusion is high, combined bypass surgery should be considered.

Key words: dissection, surgery, intracranial

Introduction

Intracranial artery dissection (IAD) is an important cause of stroke in children, young and middle-aged adults, and in the East Asian population. Although IAD is an uncommon disease, it has been recognized as a cause of subarachnoid hemorrhage (SAH) and ischemic stroke. IAD of hemorrhagic presentation requires an urgent surgical treatment to prevent hemorrhagic recurrence,¹⁾ but optimal strategies should be selected to spare the adequate blood flow for the normal brain tissue. In this review, we provide a comprehensive overview of the surgical management of IAD.

Indications of Surgical Treatment in IAD

IAD is a relatively rare cause of stroke, but it has been recognized increasingly with recent advances of the neuroimaging techniques especially among the East Asian population. IAD is one of the important causes of stroke in children, young and middle-aged adults, and most case series of IAD were reported from Asia.^{2–4)}

It has been demonstrated that the internal elastic lamina and media were disrupted in the IAD patients.^{5,6)} Additionally, the detailed pathological mechanism of IAD differs depending on the symptom. The

plane of dissection is mainly in subintimal space in the IAD presenting with ischemia. Enlargement of subintimal space may lead to the stenosis of the true lumen of parent artery, which may result in brain infarction. On the other hand, if the plane of dissection extends to subadventitial space, patients will present with hemorrhage, compression sign of brainstem, or cranial nerves.^{7–9)}

Since rebleeding occurs frequently in ultra-early stage in ruptured IAD, which may result in severe outcome, urgent surgical or endovascular treatment to prevent rebleeding should be performed.^{1,5,10,11)} Mizutani et al. reported that majority of dissecting aneurysms had one entrance into the pseudolumen (entry-only type) but some aneurysms had both entrance and exit (entry-exit type).¹²⁾ They suggested that entry-only type is unstable and rebleeding can easily occur, so that most cases of ruptured IAD are fragile and should be treated to prevent rebleeding.

On the other hand, since the natural course of IAD without hemorrhage was relatively good, indication of the surgical treatment for unruptured IAD is still controversial.^{2,13,14)}

Antithrombotic therapy might be the first-line treatment for unruptured IAD presenting with ischemic stroke. The choice of antithrombotic agent (anticoagulants or antiplatelets) has not been assessed in randomized controlled trials.

Besides, several papers have reported that unruptured IAD had bled during the course of conservative

treatment. Mizutani demonstrated that most IAD causing SAH bled within a few days after onset of dissection indicated by preceding headache.¹⁵ Since it was reported that serial angiographic change was seen in 88.2% of unruptured vertebral artery (VA) dissection and it may be amenable for surgical treatment,¹⁶ a follow-up angiography should be recommended during the early stage (within approximately 3 weeks after onset).^{16,17} Moreover, another paper reported that unruptured VA dissection had bled 4 months after onset.¹⁸ Consequently, even unruptured IAD should be followed carefully at least a few months by neuroimaging, and surgical treatment may be considered if the formation or enlargement of the aneurysmal dilatation has been confirmed.

Surgical Strategy

1. Vertebral artery

VA is the most frequently affected site in IAD. In the nationwide study of IAD in Japan, 82% of IAD is located in VA.³ There are several treatment strategies for VA dissection; proximal occlusion,

trapping (surgical or endovascular) with or without extracranial-intracranial (EC-IC) bypass, clipping or wrapping of the aneurysm sac,^{19,20} stent-assisted coil embolization of the aneurysm sac,²¹ and stent monotherapy including the use of flow diverters^{22,23} (Fig. 1). Therapeutic safety and efficacy of endovascular and surgical treatment have not been tested in a randomized trial. Recently, endovascular (internal) trapping is undertaken more frequently than surgical treatment for ruptured intracranial VA dissection.²⁴ Although internal trapping is effective to avoid rebleeding and less invasive, postoperative medullary infarctions remains unresolved.²⁵

Recent nationwide study of vertebrobasilar artery dissections in Japan demonstrated that craniotomy accounted for 20% of all intervention (including surgical and endovascular treatment), and trapping was the most frequent (62.5%) procedures in the craniotomy.²⁶ Since proximal occlusion cannot completely block the retrograde flow from the contralateral VA, trapping will be most effective to prevent rebleeding.²⁷ However, it was reported that higher incidence of ischemic complication was observed in trapping than proximal occlusion.²⁶

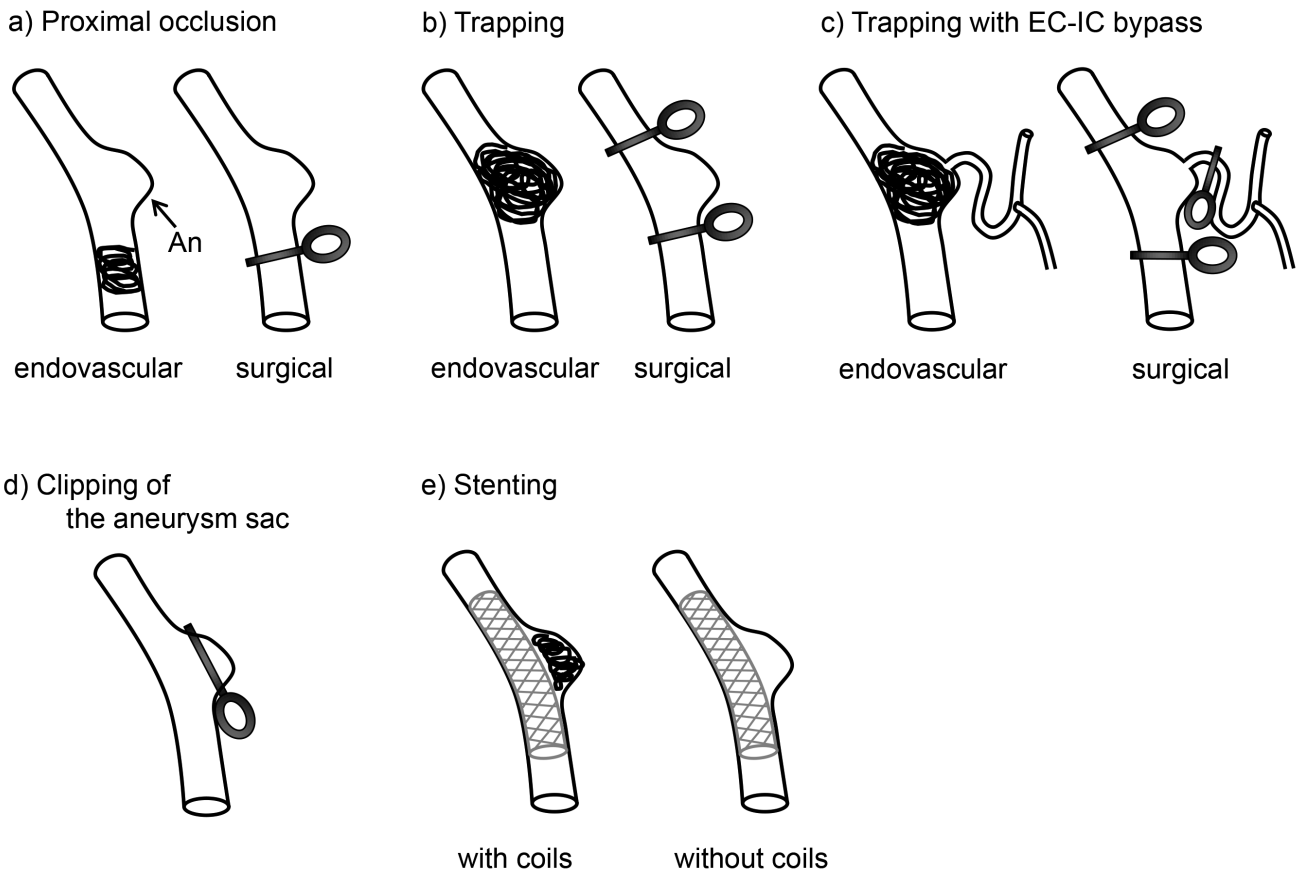


Fig. 1 Treatment strategies for vertebral artery dissecting aneurysms. An: aneurysm, EC-IC: extracranial-intracranial.

These facts suggested that an appropriate treatment should be selected on a case-by-case basis.

If the affected VA is dominant, occlusion of the parent artery may cause the ischemic complications, depending on the size of contralateral VA and posterior communicating artery. If the patient is shown to tolerate temporary occlusion of the dominant VA at the balloon test occlusion (BTO), permanent occlusion seems to be feasible.²⁸⁾ If intolerable, stent-assisted coil embolization or stent monotherapy including flow diverter may be a treatment option. Other treatment options are clipping or wrapping of the aneurysm sac,^{19,20)} occlusion of affected VA combined with EC-IC bypass [superficial temporal artery (STA) to posterior cerebral artery (PCA) or superior cerebellar artery (SCA)],²⁹⁾ and reconstruction of the affected VA using radial artery (RA), V3-to-V4 bypass grafting.^{30,31)}

The surgical treatment for VA dissection involving posterior inferior cerebellar artery (PICA) is still controversial. Although proximal occlusion is simple, it has the risk of rebleeding due to the retrograde flow.^{27,32)} Trapping without bypass can avoid rebleeding, but it has the risk of infarction in the PICA territory including

inadvertent occlusion of brainstem perforators.³³⁾ Therefore, trapping combined with occipital artery (OA)-PICA bypass³⁴⁾ or PICA side-to-side anastomosis³⁵⁾ seems an optimal treatment strategy for PICA-involved VA dissection, but it is relatively an invasive procedure for the poor grade patients. Iihara et al. proposed a reasonable management strategy for PICA-involved VA dissection that proximal endovascular occlusion is performed in the acute stage followed by clipping of the origin of the PICA with revascularization of the PICA territory if the aneurysm size does not decrease^{17,36)} (Fig. 2).

2. Basilar artery

Basilar artery (BA) dissection is very rare, and treatment for BA dissection is still challenging. Clinical manifestations are SAH, brainstem compression, and ischemia, which may result in severe outcome. Endovascular treatment including stent-assisted embolization, stent monotherapy with flow diverters might be the treatment options.³⁷⁾ Additionally, bilateral VA or BA occlusion may be effective for BA dissection if the collateral flow from the posterior communicating arteries is sufficient.^{38,39)}

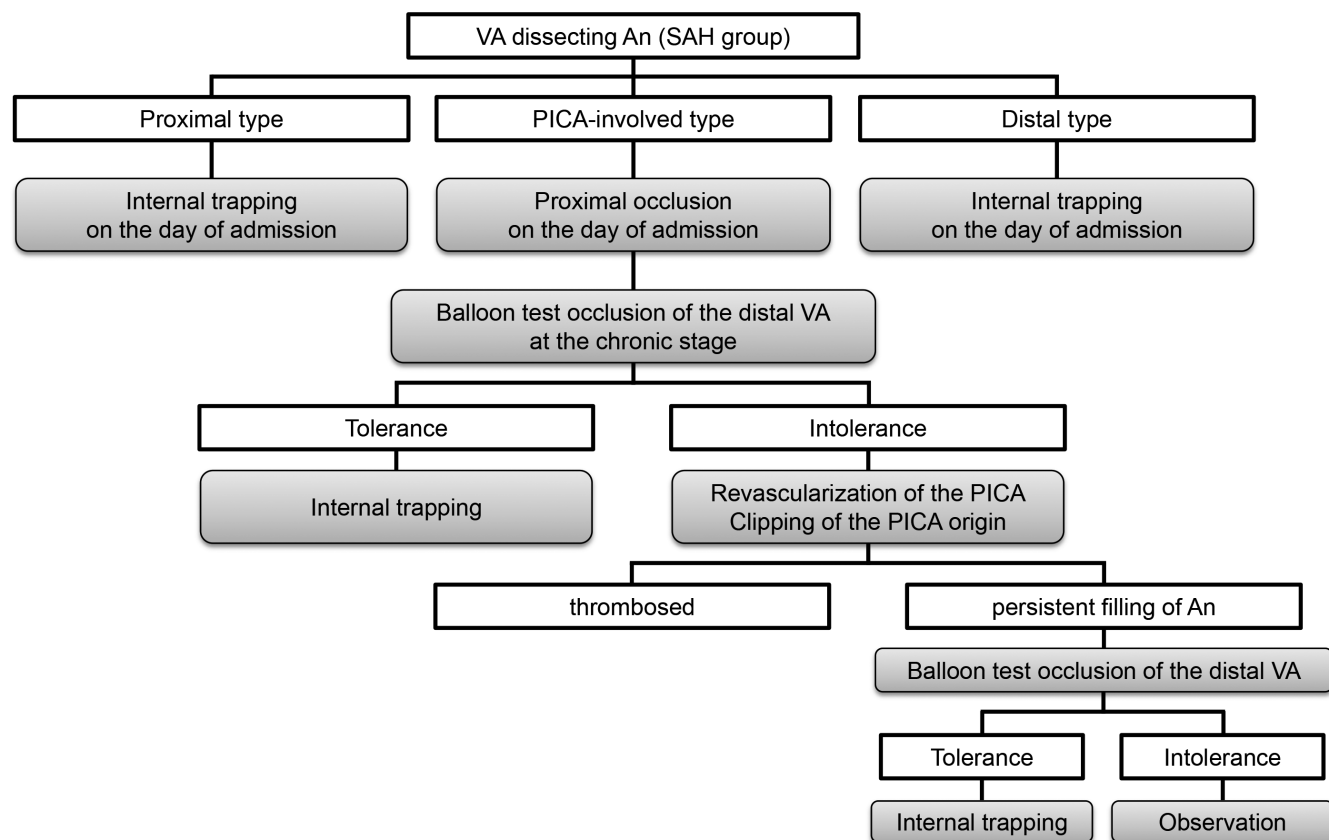


Fig. 2 Proposed management strategy for VA dissecting aneurysms. An: aneurysm, PICA: posterior inferior cerebellar artery, SAH: subarachnoid hemorrhage, VA: vertebral artery. (Figure reproduced from Reference 17.)

3. Internal carotid artery

IAD of the internal carotid artery is mainly the “blood blister-like” aneurysm (BBA) of C2 anterior wall. Because BBA is usually fragile, the rate of intraoperative rebleeding is higher than saccular aneurysm, so that the treatment of BBA is still challenging.^{40–44} In the systematic review of BBA, the overall mortality of all treatment modalities (surgical, endovascular, and conservative treatments) was 19%, and the estimated morbidity (modified Rankin Scale > 2 or reported neurological deficit after the procedure) was 17%.⁴⁵

The treatment strategies for BBA are as follows: trapping (surgical or endovascular) with or without bypass, clipping,⁴⁶ clipping on wrapping,^{47–49} coil embolization, and stenting including flow diverters.^{50–52} Since regrowth and rerupture of BBA may occur frequently,^{40–44,53} trapping is one of the optimal treatment to prevent these complications. Vascular reconstruction with EC-IC bypass should be considered if the patient is judged intolerable to parent artery occlusion, but the assessment of tolerance with BTO is not usually feasible in acute stage because of the sedation. Therefore, EC-IC bypass is usually combined with trapping.^{42,54–56} Although the choice of bypass (low flow bypass or high flow bypass) remains elusive, recent reports have suggested that high flow bypass should be better as a substitute for the normal ICA.^{53,54,56,57} High flow bypass prior to trapping reduces the risk of global cortical ischemia in case with intraoperative rebleeding. Additionally, Oono et al. suggested that high flow bypass should be selected if operated in the acute stage after SAH just in case vasospasm may occur in the collateral vessels.⁵³ Clipping or clipping on wrapping method might be considered if possible because it has an advantage of preserving the antegrade blood flow,^{46–49} but it has the risk of ischemic complication if intraoperative rebleeding occurs.

4. Middle cerebral artery

Middle cerebral artery (MCA) dissection is a very rare cause of stroke. Most cases were young, presenting with ischemic stroke (68.9%), M1 dissections accounted for 75%, and most cases were reported from the Asian countries.⁵⁸ Surgical strategies for MCA dissection are as follows: trapping,⁵⁹ wrapping or coating,^{60,61} clipping, resection^{62–64} with or without EC-IC bypass for hemorrhage, and EC-IC bypass only⁶⁵ for ischemia. Furthermore, dissected segment might be resected with reanastomosis of the arterial stumps. If the affected lesion includes large perforating artery, trapping or resection may result in ischemia so that wrapping or coating might be considered. If the lesion is located in the

distal MCA, resection or trapping with or without vascular reconstruction may be recommended to prevent rebleeding.

5. Anterior cerebral artery

Suzuki et al. reported the review of the nontraumatic arterial dissection of the anterior cerebral artery (ACA).⁶⁶ They have demonstrated that cerebral infarction (or ischemic presentation) caused by ACA dissection accounted for 58% of all ACA dissection cases, which was mostly located in A2 segment, and the prognosis was relatively good with conservative treatment. On the other hand, they also have demonstrated that hemorrhage caused by ACA dissection accounted for 31% of all cases, which was mostly located in A1 segment and surgical treatment had been performed. Surgical strategies are as follows: trapping with or without bypass,^{12,67} clipping,⁶⁸ and wrapping.⁶⁹ The strategies of bypass surgery for ACA territory are A3–A3 side-to-side anastomosis, STA-ACA anastomosis, and RA, STA-to-A3 bypass grafting.^{12,65,70–73}

Conclusion

IAD is one of the important causes of stroke, and recognized increasingly with recent advances of the neuroimaging technique especially among the East Asian population. Since rebleeding occurs frequently in the acute stage in the ruptured IAD, urgent surgical treatment should be performed to prevent rebleeding. On the other hand, surgical treatment for unruptured IAD is controversial because it has little risk for bleeding. Surgical treatment for unruptured IAD may be considered if the formation or enlargement of the aneurysmal dilatation has been confirmed.

There are several surgical strategies for IAD, and it is important to select an appropriate strategy on a case-by-case basis. If the risk of infarction due to parent artery occlusion is high, additional bypass surgery should be considered.

Conflicts of Interest Disclosure

All authors who are members of Japan Neurosurgical Society (JNS) have registered online self-reported COI Disclosure Statement Forms through the website for JNS members. K.A. has no interests to declare. K.I. received grants from Nihon Medi-Physics, Otsuka Pharmaceutical Co., Ltd., AstraZeneca K.K.

References

- 1) Mizutani T, Aruga T, Kirino T, Miki Y, Saito I, Tsuchida T: Recurrent subarachnoid hemorrhage from untreated ruptured vertebrobasilar dissecting

- aneurysms. *Neurosurgery* 36: 905–911; discussion 912–913, 1995
- 2) Li S, Yan B, Kaye A, Mitchell P, Dowling R, Collins M, Davis S: Prognosis of intracranial dissection relates to site and presenting features. *J Clin Neurosci* 18: 789–793, 2011
 - 3) Yamaura A, Yoshimoto T, Hashimoto N, Ono J: Nationwide study of nontraumatic intracranial arterial dissection: clinical features and outcome. *Surgery for Cerebral Stroke* 26: 79–86, 1998 (Japanese)
 - 4) DeBette S, Compter A, Labeyrie MA, Uyttenboogaart M, Metso TM, Majersik JJ, Goeggel-Simonetti B, Engelter ST, Pezzini A, Bijlenga P, Southerland AM, Naggara O, Béjot Y, Cole JW, Ducros A, Giacalone G, Schilling S, Reiner P, Sarikaya H, Welleweerd JC, Kappelle LJ, de Borst GJ, Bonati LH, Jung S, Thijs V, Martin JJ, Brandt T, Grond-Ginsbach C, Kloss M, Mizutani T, Minematsu K, Meschia JF, Pereira VM, Bersano A, Touzé E, Lyrer PA, Leys D, Chabriat H, Markus HS, Worrall BB, Chabrier S, Baumgartner R, Stapf C, Tatlisumak T, Arnold M, Bousser MG: Epidemiology, pathophysiology, diagnosis, and management of intracranial artery dissection. *Lancet Neurol* 14: 640–654, 2015
 - 5) Ono H, Nakatomi H, Tsutsumi K, Inoue T, Teraoka A, Yoshimoto Y, Ide T, Kitanaka C, Ueki K, Imai H, Saito N: Symptomatic recurrence of intracranial arterial dissections: follow-up study of 143 consecutive cases and pathological investigation. *Stroke* 44: 126–131, 2013
 - 6) 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* 110: 948–954, 2009
 - 7) Peluso JP, van Rooij WJ, Sluzewski M, Beute GN, Majoie CB: Endovascular treatment of symptomatic intradural vertebral dissecting aneurysms. *AJNR Am J Neuroradiol* 29: 102–106, 2008
 - 8) Yoon W, Seo JJ, Kim TS, Do HM, Jayaraman MV, Marks MP: Dissection of the V4 segment of the vertebral artery: clinicoradiologic manifestations and endovascular treatment. *Eur Radiol* 17: 983–993, 2007
 - 9) Kim BM, Suh SH, Park SI, Shin YS, Chung EC, Lee MH, Kim EJ, Koh JS, Kang HS, Roh HG, Won YS, Chung PW, Kim YB, Suh BC: Management and clinical outcome of acute basilar artery dissection. *AJNR Am J Neuroradiol* 29: 1937–1941, 2008
 - 10) Anxionnat R, de Melo Neto JF, Bracard S, Lacour JC, Pinelli C, Civit T, Picard L: Treatment of hemorrhagic intracranial dissections. *Neurosurgery* 53: 289–300; discussion 300–301, 2003
 - 11) Sugiu K, Tokunaga K, Watanabe K, Sasahara W, Ono S, Tamiya T, Date I: Emergent endovascular treatment of ruptured vertebral artery dissecting aneurysms. *Neuroradiology* 47: 158–164, 2005
 - 12) Mizutani T, Kojima H, Asamoto S, Miki Y: Pathological mechanism and three-dimensional structure of cerebral dissecting aneurysms. *J Neurosurg* 94: 712–717, 2001
 - 13) Yamaura A, Yoshimoto T, Hashimoto N, Ono J: Nationwide study of nontraumatic intracranial arterial dissection: Treatment and its results. *Surgery for Cerebral Stroke* 26: 87–95, 1998 (Japanese)
 - 14) Yoshimoto Y, Wakai S: Unruptured intracranial vertebral artery dissection. Clinical course and serial radiographic imagings. *Stroke* 28: 370–374, 1997
 - 15) Mizutani T: Natural course of intracranial arterial dissections. *J Neurosurg* 114: 1037–1044, 2011
 - 16) Nakagawa K, Touho H, Morisako T, Osaka Y, Tatsuzawa K, Nakae H, Owada K, Matsuda K, Karasawa J: Long-term follow-up study of unruptured vertebral artery dissection: clinical outcomes and serial angiographic findings. *J Neurosurg* 93: 19–25, 2000
 - 17) Iihara K, Sakai N, Murao K, Sakai H, Higashi T, Kogure S, Takahashi JC, Nagata I: Dissecting aneurysms of the vertebral artery: a management strategy. *J Neurosurg* 97: 259–267, 2002
 - 18) Takita K, Shirato H, Akasaka T, Hukazawa H: [Dissecting aneurysm of the vertebro-basilar artery—a case report and review of previous cases (author's transl)]. *No To Shinkei* 31: 1211–1218, 1979 (Japanese)
 - 19) Nakajima S, Tsukahara T, Minematsu K: A study of vertebrobasilar artery dissection with subarachnoid hemorrhage. *Acta Neurochir Suppl* 107: 45–49, 2010
 - 20) Yamaura A, Watanabe Y, Saeki N: Dissecting aneurysms of the intracranial vertebral artery. *J Neurosurg* 72: 183–188, 1990
 - 21) Suzuki S, Kurata A, Iwamoto K, Sato K, Niki J, Miyazaki T, Yamada M, Oka H, Fujii K, Kan S: Endovascular surgery using stents for vertebral artery dissecting aneurysms and a review of the literature. *Minim Invasive Neurosurg* 51: 193–198, 2008
 - 22) Narata AP, Yilmaz H, Schaller K, Lovblad KO, Pereira VM: Flow-diverting stent for ruptured intracranial dissecting aneurysm of vertebral artery. *Neurosurgery* 70: 982–988; discussion 988–989, 2012
 - 23) Park SI, Kim BM, Kim DI, Shin YS, Suh SH, Chung EC, Kim SY, Kim SH, Won YS: Clinical and angiographic follow-up of stent-only therapy for acute intracranial vertebrobasilar dissecting aneurysms. *AJNR Am J Neuroradiol* 30: 1351–1356, 2009
 - 24) Satow T, Ishii D, Iihara K, Sakai N; JR-NET Study Group: Endovascular treatment for ruptured vertebral artery dissecting aneurysms: results from Japanese Registry of Neuroendovascular Therapy (JR-NET) 1 and 2. *Neurol Med Chir (Tokyo)* 54: 98–106, 2014
 - 25) Endo H, Matsumoto Y, Kondo R, Sato K, Fujimura M, Inoue T, Shimizu H, Takahashi A, Tominaga T: Medullary infarction as a poor prognostic factor after internal coil trapping of a ruptured vertebral artery dissection. *J Neurosurg* 118: 131–139, 2013
 - 26) Tajima Y, Ono J, Higuchi Y, Machida T, Saeki N, Yamaura A: A nationwide study of intracranial arterial dissection in the vertebrobasilar system (Part 2): outcomes in hemorrhagic-onset cases. *Surgery for Cerebral Stroke* 43: 252–256, 2015 (Japanese)
 - 27) Takai N, Ezuka I, Sorimachi T, Kumagai T, Sano K: Vertebral artery dissecting aneurysm rebleeding

- after proximal occlusion—case report. *Neurol Med Chir (Tokyo)* 33: 765–768, 1993
- 28) Halbach VV, Higashida RT, Dowd CF, Fraser KW, Smith TP, Teitelbaum GP, Wilson CB, Hieshima GB: Endovascular treatment of vertebral artery dissections and pseudoaneurysms. *J Neurosurg* 79: 183–191, 1993
 - 29) Hamada J, Kai Y, Morioka M, Yano S, Todaka T, Ushio Y: Multimodal treatment of ruptured dissecting aneurysms of the vertebral artery during the acute stage. *J Neurosurg* 99: 960–966, 2003
 - 30) Kubota H, Tanikawa R, Katsuno M, Izumi N, Noda K, Ota N, Ishishita Y, Miyazaki T, Okabe S, Endo S, Niemelä M, Hashimoto M: Vertebral artery-to-vertebral artery bypass with interposed radial artery or occipital artery grafts: surgical technique and report of three cases. *World Neurosurg* 81: 202.e1–e8
 - 31) Inoue T, Tamura A, Saito I: Trapping and V3-radial artery graft-V4 bypass for ruptured dissecting aneurysm of the vertebral artery. *Neurosurg Focus* 38: Video1, 2015
 - 32) Kitanaka C, Morimoto T, Sasaki T, Takakura K: Rebleeding from vertebral artery dissection after proximal clipping. Case report. *J Neurosurg* 77: 466–468, 1992
 - 33) Mizutani T, Miki Y: Surgical considerations for PICA-involved type vertebral dissecting aneurysm. *Surgery for Cerebral Stroke* 27: 369–374, 1999 (Japanese)
 - 34) Yasui T, Komiyama M, Nishikawa M, Nakajima H: Subarachnoid hemorrhage from vertebral artery dissecting aneurysms involving the origin of the posteroinferior cerebellar artery: report of two cases and review of the literature. *Neurosurgery* 46: 196–200; discussion 200–201, 2000
 - 35) Takikawa S, Kamiyama H, Nomura M, Abe H, Saitoh H: [Vertebral dissecting aneurysm treated with trapping and bilateral posterior inferior cerebellar artery side-to-side anastomosis; case report]. *No Shinkei Geka* 19: 571–576, 1991 (Japanese)
 - 36) Mohri M, Iihara K, Murao K, Satow T, Takahashi J, Mori H, Hishikawa T, Miyamoto S: Management strategy for ruptured posterior inferior cerebellar artery (PICA)-involved vertebral artery dissecting aneurysms during the acute stage and vascular territory of the PICA. *Surgery for Cerebral Stroke* 37: 87–92, 2009 (Japanese)
 - 37) van Oel LI, van Rooij WJ, Sluzewski M, Beute GN, Lohle PN, Peluso JP: Reconstructive endovascular treatment of fusiform and dissecting basilar trunk aneurysms with flow diverters, stents, and coils. *AJNR Am J Neuroradiol* 34: 589–595, 2013
 - 38) Redekop G, TerBrugge K, Willinsky R: Subarachnoid hemorrhage from vertebrobasilar dissecting aneurysm treated with staged bilateral vertebral artery occlusion: the importance of early follow-up angiography: technical case report. *Neurosurgery* 45: 1258–1262; discussion 1262–1263, 1999
 - 39) Steinberg GK, Drake CG, Peerless SJ: Deliberate basilar or vertebral artery occlusion in the treatment of intracranial aneurysms. Immediate results and long-term outcome in 201 patients. *J Neurosurg* 79: 161–173, 1993
 - 40) Abe M, Tabuchi K, Yokoyama H, Uchino A: Blood blister-like aneurysms of the internal carotid artery. *J Neurosurg* 89: 419–424, 1998
 - 41) Sim SY, Shin YS, Cho KG, Kim SY, Kim SH, Ahn YH, Yoon SH, Cho KH: Blood blister-like aneurysms at nonbranching sites of the internal carotid artery. *J Neurosurg* 105: 400–405, 2006
 - 42) Yu-Tse L, Ho-Fai W, Cheng-Chi L, Chu-Mei K, Yi-Chou W, Tao-Chieh Y: Rupture of symptomatic blood blister-like aneurysm of the internal carotid artery: clinical experience and management outcome. *Br J Neurosurg* 26: 378–382, 2012
 - 43) Hongo K, Sato A, Kakizawa Y, Miyahara T, Tanaka Y, Sugiyama T: The nationwide surveillance on the dorsal aneurysm of the internal carotid artery: part 1: analysis of the factors affecting the poor outcome. *Surgery for Cerebral Stroke* 34: 366–371, 2006 (Japanese)
 - 44) Sato A, Hongo K, Sugiyama T, Ishihara S, Yamane F, Kakizawa Y: The nationwide surveillance on the dorsal aneurysm of the internal carotid artery part 2: Study on the surgical treatment in hemorrhagic cases. *Surgery for Cerebral Stroke (Jpn)* 34: 372–376, 2006 (Japanese)
 - 45) Gonzalez AM, Narata AP, Yilmaz H, Bijlenga P, Radovanovic I, Schaller K, Lovblad KO, Pereira VM: Blood blister-like aneurysms: single center experience and systematic literature review. *Eur J Radiol* 83: 197–205, 2014
 - 46) Ogawa A, Suzuki M, Ogasawara K: Aneurysms at nonbranching sites in the surpaclinoid portion of the internal carotid artery: internal carotid artery trunk aneurysms. *Neurosurgery* 47: 578–583; discussion 583–586, 2000
 - 47) Fujioka S, Nishi T, Koga K, Goto T, Hamada K, Tsuiki H, Kaji M, Sumi K: Ruptured blister-like aneurysm originating from the anterior wall of internal carotid artery: counterplans for pitfalls in diagnosis and treatment. *Surgery for Cerebral Stroke* 36: 38–44, 2008 (Japanese)
 - 48) Kubo Y, Ogasawara K, Tomitsuka N, Otawara Y, Watanabe M, Ogawa A: Wrap-clipping with polytetrafluoroethylene for ruptured blister-like aneurysms of the internal carotid artery. Technical note. *J Neurosurg* 105: 785–787, 2006
 - 49) Kurokawa Y, Wanibuchi M, Ishiguro M, Inaba K: New method for oblitative treatment of an anterior wall aneurysm in the internal carotid artery: encircling silicone sheet clip procedure—technical case report. *Neurosurgery* 49: 469–472, 2001
 - 50) Fiorella D, Albuquerque FC, Deshmukh VR, Woo HH, Rasmussen PA, Masaryk TJ, McDougall CG: Endovascular reconstruction with the Neuroform stent as monotherapy for the treatment of uncoilable intradural pseudoaneurysms. *Neurosurgery* 59: 291–300; discussion 291–300, 2006
 - 51) Kim BM, Chung EC, Park SI, Choi CS, Won YS: Treatment of blood blister-like aneurysm of the

- internal carotid artery with stent-assisted coil embolization followed by stent-within-a-stent technique. Case report. *J Neurosurg* 107: 1211–1213, 2007
- 52) Park JH, Park IS, Han DH, Kim SH, Oh CW, Kim JE, Kim HJ, Han MH, Kwon OK: Endovascular treatment of blood blister-like aneurysms of the internal carotid artery. *J Neurosurg* 106: 812–819, 2007
- 53) Oono T, Iihara K, Takahashi J, Nakajima N, Satow T, Takada H, Hishikawa T, Funaki T, Okawa M, Egashira Y, Masuda K, Nagata I, Miyamoto S: Treatment strategy for ruptured aneurysms originating from the anterior wall of the internal carotid artery. *Jpn J Neurosurg (Tokyo)* 18: 450–457, 2009 (Japanese)
- 54) Ishikawa T, Mutoh T, Nakayama N, Yasuda H, Nomura M, Kazumata K, Moroi J, Yasui N: Universal external carotid artery to proximal middle cerebral artery bypass with interposed radial artery graft prior to approaching ruptured blood blister-like aneurysm of the internal carotid artery. *Neurol Med Chir (Tokyo)* 49: 553–558, 2009
- 55) Baskaya MK, Ahmed AS, Ateş O, Niemann D: Surgical treatment of blood blister-like aneurysms of the supraclinoid internal carotid artery with extracranial-intracranial bypass and trapping. *Neurosurg Focus* 24: E13, 2008
- 56) Fujimura M, Shimizu H, Inoue T, Kimura N, Ezura M, Uenohara H, Tominaga T: High flow EC-IC bypass and aneurysmal trapping for ruptured IC anterior wall aneurysm: postoperative evaluation of SPECT and MRI/MRA findings in the acute stage. *Surgery for Cerebral Stroke* 41: 201–206, 2013 (Japanese)
- 57) Endo H, Fujimura M, Shimizu H, Inoue T, Sato K, Niizuma K, Tominaga T: Cerebral Blood Flow after Acute Bypass with Parent Artery Trapping in Patients with Ruptured Supraclinoid Internal Carotid Artery Aneurysms. *J Stroke Cerebrovasc Dis* 24: 2358–2368, 2015
- 58) Asaithambi G, Saravanapavan P, Rastogi V, Khan S, Bidari S, Khanna AY, Ganti L, Qureshi AI, Hedna VS: Isolated middle cerebral artery dissection: a systematic review. *Int J Emerg Med* 7: 44, 2014
- 59) Anzai K, Sasaki T, Nakagawara J, Hayase K, Nakamura H: Three dissecting aneurysms of the middle cerebral artery with subarachnoid hemorrhage. *Surgery for Cerebral Stroke* 27: 198–202, 1999 (Japanese)
- 60) Kawaguchi T, Kawano T, Kazekawa K, Honma T, Kaneko Y, Koizumi T, Dousaka Y: [Dissecting aneurysm of the middle cerebral artery with subarachnoid hemorrhage and brain infarction: a case report]. *No Shinkei Geka* 25: 1033–1037, 1997 (Japanese)
- 61) Nimura T, Oku T, Narita N, Higuchi H: [Dissecting aneurysm of the middle cerebral artery: case report]. *No Shinkei Geka* 28: 61–65, 2000 (Japanese)
- 62) Piepgras DG, McGrail KM, Tazelaar HD: Intracranial dissection of the distal middle cerebral artery as an uncommon cause of distal cerebral artery aneurysm. Case report. *J Neurosurg* 80: 909–913, 1994
- 63) Hashimoto N, Suzuki O, Takakubo Y, Mori I, Nagai H: A dissecting aneurysm of the middle cerebral artery : a case report. *Jpn J Neurosurg (Tokyo)* 4: 281–286, 1994 (Japanese)
- 64) Sasaki O, Koike T, Tanaka R, Ogawa H: Subarachnoid hemorrhage from a dissecting aneurysm of the middle cerebral artery. Case report. *J Neurosurg* 74: 504–507, 1991
- 65) Kitani R, Itouji T, Noda Y, Kimura M, Uchida S: Dissecting aneurysms of the anterior circle of Willis arteries. Report of two cases. *J Neurosurg* 67: 296–300, 1987
- 66) Suzuki I, Nishino A, Nishimura S, Numagami Y, Suzuki H, Utsunomiya A, Suzuki S, Uenohara H, Sakurai Y: [Nontraumatic arterial dissection of the anterior cerebral artery: six cases report]. *No To Shinkei* 57: 509–515, 2005 (Japanese)
- 67) Kamiyama H: [Bypass with radial artery graft]. *No Shinkei Geka* 22: 911–924, 1994 (Japanese)
- 68) Honda N, Yuge T, Miyagi J, Shigemori M: A surgical case of dissecting aneurysm of the anterior cerebral artery. *Jpn J Neurosurg (Tokyo)* 6: 634–638, 1997 (Japanese)
- 69) Kato M, Tanaka Y, Kuroda T, Nakashima T, Hattori T: A case of dissecting aneurysm of the peripheral anterior cerebral artery causing subarachnoid hemorrhage. *Surgery for Cerebral Stroke* 37: 288–293, 2009 (Japanese)
- 70) Yasukawa K, Kamijo Y, Momose G, Kobayashi S, Ikeda A: A case of anterior cerebral artery dissecting aneurysm presenting subarachnoid hemorrhage and cerebral infarction at the same time. *Surgery for Cerebral Stroke* 21: 461–466, 1993 (Japanese)
- 71) Nagata K, Sato K: Surgical treatment for the dissecting aneurysm of the anterior. *Surgery for Cerebral Stroke* 24: 80–84, 1996 (Japanese)
- 72) Tanikawa R, Anei R, Izumi N, Hashizume A, Fujita T, Hashimoto M, Kamiyama H: Strategy of treatment for anterior cerebral artery dissection. *Surgery for Cerebral Stroke* 27: 433–438, 1999 (Japanese)
- 73) Arimura K, Hitotsumatsu T, Ishido K, Ito O: Non-traumatic anterior cerebral artery dissection with cerebral infarction followed by subarachnoid hemorrhage treated by trapping and bypass: a case report. *Jpn J Neurosurg (Tokyo)* 16: 863–867, 2007 (Japanese)

Address reprint requests to: Koji Iihara, MD, PhD, Department of Neurosurgery, Graduate School of Medical Sciences, Kyushu University, 3-1-1 Maidashi, Higashi-ku, Fukuoka, Fukuoka 812-8582, Japan. e-mail: kiihara@ns.med.kyushu-u.ac.jp