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High-flow bypass using saphenous vein grafts with trapping of ruptured blood blister-like aneurysms of the internal carotid artery: patient series

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BACKGROUND Trapping an aneurysm after the establishment of an extracranial to intracranial high-flow bypass is considered the optimal surgical strategy for ruptured blood blister–like aneurysms (BBAs) of the internal carotid artery (ICA). For high-flow bypass surgeries, a radial artery graft is generally preferred over a saphenous vein graft (SVG). However, SVGs can be advantageous in acute-phase surgeries because of their greater length, easy manipulability, ability to act as high-flow conduits, and reduced risk of vasospasms. In this study, the authors presented five cases of ruptured BBAs treated with high-flow bypass using an SVG followed by BBA trapping, and they reported on surgical outcomes and operative nuances that may help avoid potential pitfalls.

OBSERVATIONS After the surgeries, there were no ischemic or hemorrhagic complications, including symptomatic vasospasms. In three of the five cases, postoperative modified Rankin scale scores were between 0 and 2 at the 3-month follow-up. In one case, the SVG spontaneously occluded after surgery while the protective superficial temporal artery (STA) to middle cerebral artery (MCA) bypass became dominant, and the patient experienced no ischemic symptoms.

LESSONS High-flow bypass using an SVG with a protective STA-MCA bypass followed by BBA trapping is a safe and effective treatment strategy.

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KEYWORDS blood blister–like aneurysm; high flow bypass; internal carotid artery; saphenous vein; subarachnoid hemorrhage; trapping

Blood blister–like aneurysms (BBAs) usually occur in the supraclinoid internal carotid artery (ICA). The walls of these aneurysms are fragile because of adventitia, fibrous tissue composition, lack of internal elastic lamina, and media layers.[1] These pathological aspects render trapping of these aneurysms, after establishment of an extracranial to intracranial high-flow bypass, the optimal strategy for ruptured BBAs.[2] The saccular type can be treated by direct clipping or coil embolization, whereas the blister type requires clipping on the wrapping material. Recently, with the development of endovascular surgery, reconstructive endovascular treatments are the preferred treatments,[3,4] and a flow diverter stent is starting to be used.[5] The flow diverter stent carries a higher complication rate in the acute rupture setting than in cases of unruptured aneurysms. Double antiplatelet treatment still remains challenging, especially in ruptured aneurysms.[6] Some cases cannot be treated by endovascular treatment because of access problems or contrast allergy.

Therefore, direct surgery is a reliable alternative treatment. Radial artery grafts (RAGs) are commonly used for high-flow bypass surgeries because of their valve-free structure and ease of anastomosis to the intracranial artery. Conversely, saphenous vein grafts (SVGs) are generally not preferred over RAGs. However, SVGs have distinct advantages, including their length, easy manipulability, ability to act as high-flow conduits, and reduced risk of vasospasms,[2,7] which may provide more versatility for acute phase surgeries involving inadequate opportunities for examination. To date, few case reports on high-flow bypasses using SVGs for ruptured BBAs are available, and

ABBREVIATIONS 3D = three dimensional; BBA = blood blister–like aneurysm; CT = computed tomography; ICA = internal carotid artery; MCA = middle cerebral artery; MRA = magnetic resonance angiography; mRS = modified Rankin scale; PCOM = posterior communicating; RAG = radial artery graft; SAH = subarachnoid hemorrhage; STA = superficial temporal artery; SVG = saphenous vein graft; WFNS = World Federation of Neurosurgical Societies.

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the surgical outcomes are not well known. Here, we present a case series of patients with ruptured BBAs who were preferentially treated by high-flow bypass using an SVG and BBA trapping and report the operative nuances undertaken to avoid potential pitfalls.

Study Description

Study Cohort

Five consecutive patients with subarachnoid hemorrhage (SAH) due to ruptured BBAs were retrospectively identified between January 2016 and December 2019. All BBAs were preoperatively diagnosed according to three-dimensional (3D) computed tomography (CT) angiography or digital subtraction angiography images. In all cases, BBA trapping was performed after high-flow bypass using an SVG that anastomosed the external carotid artery (ECA) to the middle cerebral artery (MCA).[8] Before anastomosing a high-flow bypass, superficial temporal artery (STA) to MCA single/double-barrel bypass was performed to ensure distal blood flow while facilitating the high-flow bypass.

Surgical Procedure

After exposing the cervical common carotid artery, ECA, and ICA, a curved skin incision was made over the parietal branch of the STA, and the frontal branch of the STA was dissected for the double bypass (Fig. 1A and B). The artificial vessel (GORE-TEX, 5–6 mm) was passed through the deep temporal muscle, zygomatic arch, and digastric muscle to introduce the SVG (Fig. 1C). The M2 segment of the MCA was identified as the recipient of the high-flow bypass. The harvested side of the SVG was selected according to the vessel size evident on the preoperative nonenhanced 3D CT venography image and harvested from the ankle to the knee (Fig. 1D). Branches of the saphenous vein were ligated with 3-0 silk threads. After harvesting the SVG, venous valves near the cut end were removed (Fig. 1E). SVGs have venous valves with an average interval distance of 5.1 cm.[9] The valves near the anastomotic orifice may cause thrombotic occlusion. Therefore, after harvesting the SVG, we checked the proximal and distal cut ends and performed a valvotomy if there was a venous valve within 10 mm of the cut end. In addition, the SVGs were used in a reversed position to allow unrestricted blood to flow via the venous valves. The graft was irrigated and filled with heparinized saline from the distal side (Fig. 1F). The SVG was then passed through an artificial blood vessel to prevent twisting and bending (Fig. 1G and H). SVGs are generally less resistant to kinking and torsion than arterial grafts. Therefore, we routinely place an artificial vessel under the digastric muscle and through the bottom of the zygomatic arch to create a subcutaneous tunnel for introducing the SVG. The artificial vessel can prevent kinking and torsion of the SVG during subcutaneous penetration.

Before anastomosing the SVG, a protective STA-MCA bypass was performed on the cortical artery on the distal side of the SVG recipient artery. When constructing a double bypass, a second anastomosis was performed on a different cortical artery branching from the M2, separate from the SVG recipient artery. Subsequently, the SVG was anastomosed to the M2 segment of the MCA using an intermittent suture containing 8-0 monofilaments. All intracranial bypasses were performed using silicone stents.[10] The M2 segment is deeper and narrower than the M3–4 segment; therefore, a good operative field should be prepared before performing the anastomosis. We created a wide field and laid a rubber sheet under the recipient artery for repositioning. We inserted a colored flexible cylindrical silicone rubber stent (300–400 μm in diameter, 3–4 mm in length) into the recipient arteries during the anastomosis. This insertion helped confirm the ostium of the transparent thin-walled recipient arteries and allowed for a more precise anastomosis. The rubber stent was removed after all sutures were placed.

The cervical side was then anastomosed to the ECA. Both high-flow and STA-MCA bypass patency were confirmed using indocyanine green angiography and Doppler ultrasonography.

Finally, we confirmed the BBA and trapped the ICA while preserving the flow of the posterior communicating (PCOM) and anterior choroidal artery. The proximal ICA was ligated onto the ophthalmic segment of the intracranial ICA. We did not use intraoperative systemic heparinization or preoperative antiplatelet therapy for cases of SAH.

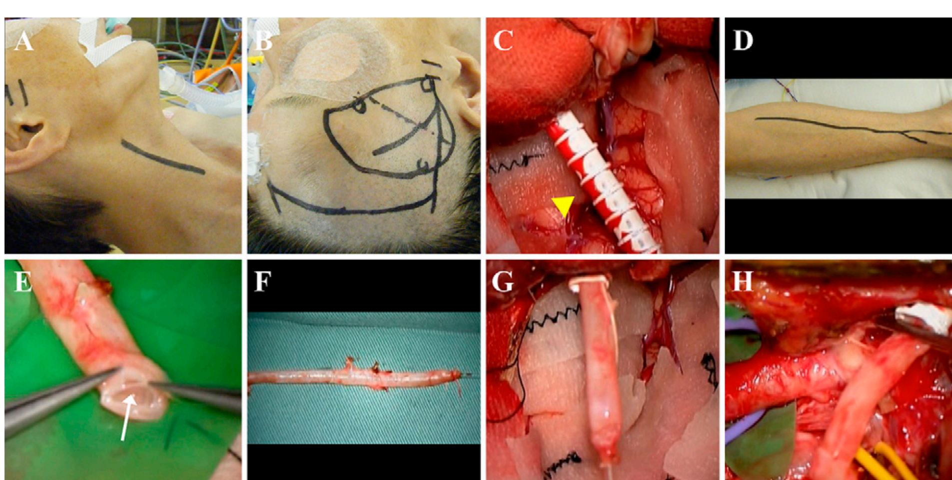

FIG. 1. A: The straight skin incision exposing the cervical carotid arteries. **B:** The curved skin incision over the parietal branch of the STA. **C:** The intraoperative view of the artificial vessel (*arrowhead*) passing under the deep temporal muscle, zygomatic arch, and digastric muscle to allow for the introduction of the SVG. **D:** The skin incision for harvest of the SVG. **E:** Venous valves near the cut end were removed. **F:** The graft was irrigated and filled with heparinized saline from the distal side. The SVG was passed through the artificial blood vessel (**G,** cranial side; **H,** cervical side).

Outcomes

Immediate morbidity, surgical complications, and postoperative outcomes were periodically assessed by neurosurgeons during the perioperative period. Postoperative ischemic or hemorrhagic complications were evaluated in all cases. The outcomes were classified according to the modified Rankin scale (mRS). Postoperative patency of both the high-flow and the STA-MCA bypass was assessed using time-of-flight magnetic resonance angiography (MRA), 3D CT angiography, or digital subtraction angiography within 7 days after surgery. The long-term patency of the bypass was evaluated 1 year after surgery.

Illustrative Cases

Case 1

A 47-year-old woman experienced a sudden onset of headaches and subsequently lapsed into a stupor. An initial head CT revealed a diffuse SAH with a World Federation of Neurosurgical Societies (WFNS) grade 3; 3D CT angiography showed a BBA located on the posterior wall of the right ICA on the distal side of the ophthalmic artery (Fig. 2A–D). The patient was transferred to our hospital and treated by establishing an ECA-SVG-MCA bypass with a protective STA-MCA bypass. This bypass was followed by BBA trapping using an oblique clipping technique to preserve the origin of the PCOM (Fig. 2E–G). The patient's postoperative course was uneventful, with no postoperative complications. Severe vasospasms did not occur during the perioperative period. Postoperative 3D CT angiography showed no recurrence of the BBA and good patency of both the high-flow and STA-MCA bypasses (Fig. 2H). She was discharged without neurological deficits.

Case 2

A 34-year-old man presented with a sudden headache and was subsequently diagnosed with a WFNS grade 1 SAH due to a BBA located on the lateral wall of the left ICA on the proximal side of the PCOM (Fig. 3A–D). He was treated by establishing an ECA-SVG-MCA bypass with a protective STA-MCA double-barrel bypass and BBA trapping while preserving the PCOM (Fig. 3E–G). His postoperative course included no complications or cerebral ischemia due to vasospasms. Although there were no ischemic symptoms, postoperative MRA demonstrated occlusion of the high-flow bypass whereas the protective STA-MCA bypass remained patent (Fig. 3H). Postoperative MRA showed occlusion of the SVG. We consider that this resulted from the higher STA-MCA bypass flow than the SVG flow. There are other causes of venous bypass occlusion, but even if occluded, double low-flow bypass also reduces ischemic complications as much as possible. Therefore, a double STA-MCA bypass and high flow bypass using an SVG were performed when the ICA was ligated. The patient was discharged without neurological deficits.

Table 1 presents a summary of the patient and aneurysmal characteristics and the perioperative and long-term outcomes. All ruptured aneurysms were located between the distal and proximal sides of the ophthalmic artery and the PCOM, respectively. In all cases, postoperative angiography showed complete resolution of the BBA. The high-flow bypass was patent in four of five cases (80%). In one case, the SVG spontaneously occluded, resulting in the protective STA-MCA bypass becoming dominant, and the patient did not suffer from any resulting ischemic symptoms. No ischemic or hemorrhagic complications or severe cerebral vasospasms required endovascular treatment during the SAH period. No complications were associated with deep venous thrombosis or the lower extremity. Fortunately, no patients required permanent ventricular drainage, tracheostomy, or gastrostomy. In three of the five cases, mRS scores at the 3-month follow-up were within the range of 0 to 2. Long-term follow-up angiography indicated that the SVG was patent in all cases except the one spontaneously occluded case mentioned above.

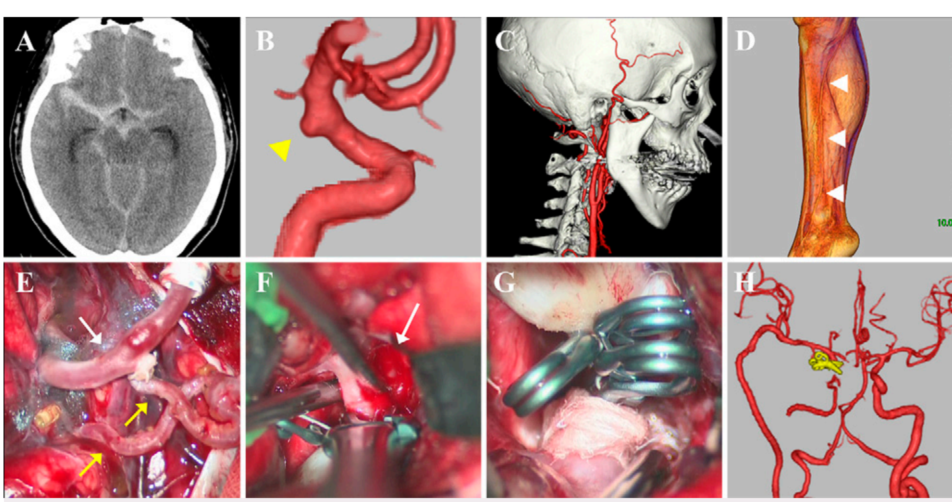

FIG. 2. A: Initial CT images of the head revealed a diffuse SAH. **B:** 3D CT angiography revealed an aneurysm (*arrowhead*) on the posterior wall of the right ICA, located on the distal side of the ophthalmic artery. **C:** Both the frontal and parietal branches of the STA were well developed. **D:** Preoperative nonenhanced 3D CT venography demonstrated an appropriate saphenous vein (*arrowheads*) for the bypass graft. **E:** The STA-M4 double bypass (*yellow arrow*) and the ECA-saphenous vein-M2 bypass (*white arrow*) were established followed by trapping of the aneurysm. **F:** The intraoperative view shows the BBA (*white arrow*) of the right ICA. **G:** The aneurysm was trapped while preserving the origin of the PCOM artery. **H:** Postoperative 3D CT angiography showed no recurrence of the BBA and patency of the high-flow bypass.

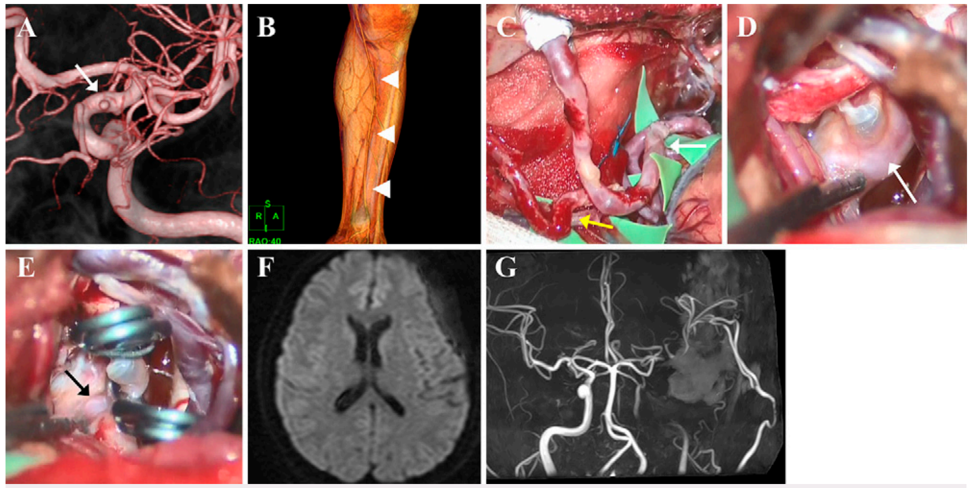

FIG. 3. A: 3D CT angiography revealed an aneurysm on the anterior wall of the left ICA (*arrow*). **B:** Nonenhanced 3D CT venography demonstrating a saphenous vein for the bypass graft (*arrowheads*). **C:** The STA-M4 bypass (*yellow arrow*) and the ECA-saphenous vein-M2 bypass (*white arrow*) were established. **D:** Intraoperative view showing a BBA (*white arrow*) in the left ICA. **E:** The aneurysm was trapped while preserving the origin of the PCOM artery (*black arrow*). **F:** Postoperative diffusion-weighted MRI showed no cerebral infarction. **G:** MRA demonstrated that the SVG was occluded, resulting in the STA-MCA assist bypass becoming dominant.

Discussion

Observations

This study presents a treatment protocol for ruptured BBA using an SVG and protective STA-MCA bypass. The treatment of ruptured BBAs of the supraclinoid ICA remains challenging, and the optimal intervention for BBAs, surgical or otherwise, has not yet been determined. Direct surgery offers potentially superior obliteration rates of aneurysms comparable to those achieved with endovascular therapy.[11,12] However, direct clipping often leads to intraoperative premature rupture, resulting in ICA sacrifice and high mortality due to subsequent strokes.[2] The wrap-on clip method is reportedly safe; however, it may not be easy to preserve the perforator branch, and the possibility of recurrence of the aneurysm was also noted.[13] Simple coil embolization and stent-assisted coil embolization for BBAs exhibited recurrence of the aneurysm or rebleeding. The recurrence of aneurysms is low with endovascular ICA trapping, but there are problems regarding tolerance and perforating arteries.[4] The stent-within-a-stent technique or covered stent placement effectively prevented rebleeding and the recurrence of the BBA without sacrificing the ICA. This can be considered an alternative treatment option for BBAs in select patients for whom ICA sacrifice is not feasible.[3] Endovascular therapy, including multilayer flow-diverting stents, may have a better safety profile and provide functional outcomes comparable to surgery, although they involve the risk of incomplete obliteration, retreatments, and higher device costs.[11,12,14] Furthermore, the requirement of dual antiplatelet therapy remains a major constraint in the background of SAHs.

BBA trapping is the safest and most reliable technique for resolving fragile aneurysms and preventing rebleeding and reoccurrence.[15] However, ICA sacrifice in the acute stages of SAH with increased intracranial pressure, hypercoagulopathy, and risk of vasospasm in collateral vessels yields inferior outcomes in the absence of cerebral revascularization.[2]

TABLE 1. A summary of patient and aneurysmal characteristics and perioperative and long-term outcomes

Case No.	Age (yrs)	Sex	WFNS Grade	Postoperative SVG Patency	Postoperative Stroke	mRS Scores at 3-Mo FU	Long-Term SVG Patency (FU period)
1	47	F	3	Yes	No	2	Yes (3 yrs)
2	34	M	1	No	No	0	No
3	55	F	5	Yes	No	5	Yes (3 yrs)
4	55	M	2	Yes	No	1	Yes (2 yrs)
5	92	F	2	Yes	No	3	Yes (1 yr)

FU = follow-up.

Revascularization methods such as STA-MCA single/double-barrel bypass or extracranial to intracranial high-flow bypass have been demonstrated in such cases. Although a complex and time-consuming approach, high-flow bypass is the most reliable method for flow replacement when sacrificing the ICA.[16,17] ICA trapping after high-flow bypass has resulted in favorable outcomes for patients with BBAs.[18] Our results suggest that revascularization, which uses a high-flow bypass with SVG and a protective STA-MCA bypass, is effective for postoperative cerebral ischemia and vasospasm during the SAH period.

Advantages of SVGs

High-flow bypass using RAGs with trapping of ruptured BBAs has commonly been reported as a practical treatment with satisfactory outcomes.[8,16,17] RAGs are generally preferred over SVGs because of the minor differences between the graft and the MCA recipient vessel diameter in SVGs. Furthermore, RAGs are easier to anastomose into M3 vessels as small as 1.5 mm.[19] Additionally, several previous studies in thoracic surgery have observed less postoperative graft occlusion with RAGs than with SVGs.[20] However, in a few reported cases, SVGs were preferred to RAGs.[20,21]

Although not preferred generally, SVGs have specific advantages: (1) They are easy to harvest and manipulate without ischemic risk, whereas harvesting of the radial artery can cause hand ischemia.[20,22] (2) A greater length of the saphenous vein can be harvested compared with the radial artery.[23] (3) They have a higher feasible flow rate (70–140 mL/min) than RAGs (70 mL/min) and are therefore more suitable for the requirements of cerebral blood flow.[19] (4) They rarely cause vasospasms, whereas RAGs are more prone to vasospasms (4%–10%), which may result in ischemic sequelae.[24] We believe that these advantages afforded by SVGs make them a superior choice in acute phase surgeries for ruptured BBAs in cases of unstable patients and inadequate opportunities for examination. Moreover, the saphenous vein can be noninvasively visualized using nonenhanced 3D CT venography, which allows for an objective evaluation of the vein before harvesting.[25] For the aforementioned reasons, we preferentially used SVGs for all cases of ruptured BBAs in this study.

Protective STA-MCA Bypass

We always performed protective STA-MCA single/double-barrel anastomosis before the high-flow bypass to decrease the risk of brain ischemia in our patients. The STA-MCA single bypass is performed on the cortical artery on the distal side of the recipient artery of the high-flow bypass. Therefore, this first STA-MCA bypass can minimize the risk of cerebral ischemia in the distal perfusion area of the recipient artery of the SVG during temporary cross-clamping for anastomosis of the SVG.

Another important role of the protective STA-MCA bypass is to ensure cerebral perfusion in the case of SVG occlusion. According to previous reports, no significant differences in graft patency were observed at the 1-year follow-up between RAGs and SVGs whereas SVG occlusion occurred in 11%–13% of cases.[20,21,26] We also experienced one case of spontaneous SVG occlusion after surgery; however, the protective STA-MCA bypass remained patent, and the patient had no repercussions. The protective STA-MCA bypass is mandatory to reduce the risk of perioperative ischemic complications.[27]

Limitations

Some limitations of the present study should be noted. First, this was a retrospective analysis of only five cases. Additional studies with a larger number of patients are necessary to validate our results.

Second, balloon test occlusion of the ipsilateral ICA was not performed, thus making it difficult to evaluate collateral filling and cross-flow. However, the reliability of balloon test occlusion in patients with acute SAH has not yet been proven. Particularly in unstable patients with a ruptured BBA, simple ICA trapping or trapping with only STA-MCA bypass might result in a higher incidence of severe ischemic complications.[2] Therefore, we prioritized high-flow bypass with trapping surgery. Optimal therapeutic strategies for ruptured BBAs still need to be investigated further.

Third, it is usually feasible to harvest a sufficient length of the saphenous vein; however, partial varicosities may render the SVG unusable. According to previous reports, there is an estimated 1.2%–4.3% incidence of saphenous vein varicosities in patients with chronic venous disease.[28] In contrast, 27% of the radial artery has potential circulatory or anatomical insufficiency, leading to ischemic complications associated with harvesting a RAG.[22] Although the choice of bypass graft may be controversial, we believe that the use of an SVG should be considered in cases of ruptured BBAs.

Lessons

Although harvesting and anastomosing an SVG involves some specific technical aspects, SVGs present several advantages and could be a superior choice in acute-phase surgeries. When optimally performed, high-flow bypass using an SVG with protective STA-MCA bypass followed by trapping of ruptured BBAs is a safe and effective strategy.

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References

1. Ogawa A, Suzuki M, Ogasawara K. Aneurysms at nonbranching sites in the supraclinoid portion of the internal carotid artery: internal carotid artery trunk aneurysms. *Neurosurgery.* 2000;47(3):578–586.
2. Meling TR, Patet G. The role of EC-IC bypass in ICA blood blister aneurysms: a systematic review. *Neurosurg Rev.* 2021;44(2): 905–914.
3. Lee BH, Kim BM, Park MS, et al. Reconstructive endovascular treatment of ruptured blood blister-like aneurysms of the internal carotid artery. *J Neurosurg.* 2009;110(3):431–436.
4. Park JH, Park IS, Han DH, et al. Endovascular treatment of blood blister-like aneurysms of the internal carotid artery. *J Neurosurg.* 2007;106(5):812–819.
5. Rasskazoff S, Silvaggio J, Brouwer PA, Kaufmann A, Nistor A, Iancu D. Endovascular treatment of a ruptured blood blister-like aneurysm with a flow-diverting stent. *Interv Neuroradiol.* 2010;16(3): 255–258.
6. Kan P, Sweid A, Srivatsan A, Jabbour P. Expanding indications for flow diverters: ruptured aneurysms, blister aneurysms, and dissecting aneurysms. *Neurosurgery.* 2020;86(suppl 1):S96–S103.
7. Jafar JJ, Russell SM, Woo HH. Treatment of giant intracranial aneurysms with saphenous vein extracranial-to-intracranial bypass grafting: indications, operative technique, and results in 29 patients. *Neurosurgery.* 2002;51(1):138–146.
8. Kawashima A, Okada Y, Kawamata T, Onda H, Kubo O, Hori T. Successful treatment of a blood blister-like aneurysm of the internal carotid artery by trapping with a high-flow bypass. *J Clin Neurosci.* 2008;15(7):797–800.
9. Schweighofer G, Mühlberger D, Brenner E. The anatomy of the small saphenous vein: fascial and neural relations, saphenofemoral junction, and valves. *J Vasc Surg.* 2010;51(4):982–989.

10. Okada Y, Shima T, Yamane K, Yamanaka C, Kagawa R. Cylindrical or T-shaped silicone rubber stents for microanastomosis: technical note. *Neurol Med Chir (Tokyo).* 1999;39(1):55–58.
11. Shah SS, Gersey ZC, Nuh M, Ghonim HT, Elhammady MS, Peterson EC. Microsurgical versus endovascular interventions for blood-blister aneurysms of the internal carotid artery: systematic review of literature and meta-analysis on safety and efficacy. *J Neurosurg.* 2017;127(6):1361–1373.
12. Szmuda T, Sloniewski P, Waszak PM, Springer J, Szmuda M. Towards a new treatment paradigm for ruptured blood blister-like aneurysms of the internal carotid artery? A rapid systematic review. *J Neurointerv Surg.* 2016;8(5):488–494.
13. Guo Y, Zhang J, Chen H, Xu K, Yu J. Suturing and dural wrapping for a blood blister-like aneurysm on the supraclinoid segment of the internal carotid artery due to dissection. *World Neurosurg.* 2018;109:165–170.
14. Zhu D, Yan Y, Zhao P, et al. Safety and efficacy of flow diverter treatment for blood blister-like aneurysm: a systematic review and meta-analysis. *World Neurosurg.* 2018;118:e79–e86.
15. Satoh A, Sugiyama T, Hongo K, Kakizawa Y, Ishihara S, Matsutani M. Nationwide surveillance of IC anterior (or dorsal) wall aneurysm: with special reference to its dissecting nature. *Acta Neurochir Suppl.* 2008;103:51–55.
16. Kamijo K, Matsui T. Acute extracranial-intracranial bypass using a radial artery graft along with trapping of a ruptured blood blister–like aneurysm of the internal carotid artery. Clinical article. *J Neurosurg.* 2010;113(4):781–785.
17. Kikkawa Y, Ikeda T, Takeda R, et al. Results of early high-flow bypass and trapping for ruptured blood blister-like aneurysms of the internal carotid artery. *World Neurosurg.* 2017;105:470–477.
18. Kazumata K, Nakayama N, Nakamura T, Kamiyama H, Terasaka S, Houkin K. Changing treatment strategy from clipping to radial artery graft bypass and parent artery sacrifice in patients with ruptured blister-like internal carotid artery aneurysms. *Neurosurgery.* 2014;10(suppl 1):66–73.
19. Sekhar LN, Duff JM, Kalavakonda C, Olding M. Cerebral revascularization using radial artery grafts for the treatment of complex intracranial aneurysms: techniques and outcomes for 17 patients. *Neurosurgery.* 2001;49(3):646–659.
20. Al-Sabti HA, Al Kindi A, Al-Rasadi K, Banerjee Y, Al-Hashmi K, Al-Hinai A. Saphenous vein graft vs. radial artery graft searching for the best second coronary artery bypass graft. *J Saudi Heart Assoc.* 2013;25(4):247–254.
21. Goldman S, Sethi GK, Holman W, et al. Radial artery grafts vs saphenous vein grafts in coronary artery bypass surgery: a randomized trial. *JAMA.* 2011;305(2):167–174.
22. Kohonen M, Teerenhovi O, Terho T, Laurikka J, Tarkka M. Is the Allen test reliable enough? *Eur J Cardiothorac Surg.* 2007;32(6): 902–905.
23. Harky A, MacCarthy-Ofosu B, Grafton-Clarke C, Pousios D, Muir AD. Long saphenous vein harvesting techniques and their effect on graft patency. *J Card Surg.* 2019;34(9):821–828.
24. Tecle NEE, Zammar SG, Hamade YJ, et al. Use of a harvested radial artery graft with preservation of the vena comitantes to reduce spasm risk and improve graft patency for extracranial to intracranial bypass: technical note. *Clin Neurol Neurosurg.* 2016;142:65–71.
25. Takahashi Y, Kokubo M, Nozaka T. Could non-contrast 3DCT-venography be the first-choice diagnostic imaging modality for the treatment of varicose vein? *Ann Vasc Dis.* 2016;9(1):8–14.
26. Regli L, Piepgras DG, Hansen KK. Late patency of long saphenous vein bypass grafts to the anterior and posterior cerebral circulation. *J Neurosurg.* 1995;83(5):806–811.
27. Aboukais R, Verbraeken B, Leclerc X, et al. Protective STA-MCA bypass to prevent brain ischemia during high-flow bypass surgery: case series of 10 patients. *Acta Neurochir (Wien).* 2019;161(6): 1207–1214.
28. Labropoulos N, Kokkosis AA, Spentzouris G, Gasparis AP, Tassiopoulos AK. The distribution and significance of varicosities in the saphenous trunks. *J Vasc Surg.* 2010;51(1):96–103.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Yamaguchi, Kawamata. Acquisition of data: Yamaguchi, Ishiguro, Ishikawa, Ottomo. Analysis and interpretation of data: Yamaguchi, Ishiguro, Ottomo. Drafting the article: Yamaguchi, Ishiguro, Kawamata. Critically revising the article: Yamaguchi, Ishiguro. Reviewed submitted version of manuscript: Yamaguchi, Ishiguro, Funatsu, Matsuoka, Omura, Kawamata. Approved the final version of the manuscript on behalf of all authors: Yamaguchi. Administrative/technical/material support: Yamaguchi, Funatsu, Matsuoka, Omura. Study supervision: Kawamata.

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