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CASE REPORT
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Revascularization of the anterior cerebral artery by Y-shaped superficial temporal artery interposition graft for the treatment of a de novo aneurysm arising at the site of A_3-A_3 bypass: technical case report

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The most frequently used option to reconstruct the anterior cerebral artery (ACA) is an ACA-ACA side-to-side anastomosis. The long-term outcome and complications of this technique are unclear. The authors report a case of a de novo aneurysm arising at the site of A_3-A_3 anastomosis. A 53-year-old woman underwent A_3-A_3 side-to-side anastomosis for the treatment of a ruptured right A_2 dissecting aneurysm. At 44 months after surgery, a de novo aneurysm developed at the site of anastomosis. The aneurysm developed in the front wall of the anastomosis site, and projected to the antero-superior direction. A computational fluid dynamics (CFD) study showed the localized region with high wall shear stress coincident with the pulsation in the front wall of the anastomosis site, where the aneurysm developed. A Y-shaped superficial temporal artery (STA) interposition graft was used successfully to reconstruct both ACAs, and then the aneurysm was trapped. To the authors' knowledge, this is the first case of a de novo aneurysm that developed at the site of an ACA-ACA side-to-side anastomosis. A CFD study showed that hemodynamic stress might be an underlying cause of the aneurysm formation. A Y-shaped STA interposition graft is a useful option to treat this aneurysm. Long-term follow-up is necessary to detect this rare complication after ACA-ACA anastomosis.

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KEY WORDS de novo aneurysm; bypass surgery; anterior cerebral artery; interposition graft; vascular disorders

Clipping and coiling are not applicable for complex intracranial aneurysms, such as giant, thrombosed, fusiform, or dissecting aneurysms. Trapping with revascularization is a therapeutic option for these types of aneurysms. For anterior cerebral artery (ACA) aneurysms, revascularization techniques are much more complicated than other techniques because of their deep location in the interhemispheric fissure.[1,19] There are many technical options and variations for revascularization of ACAs.[1,8,14,19,23] The most reasonable and simplest option to reconstruct one side of the ACA is an ACA-ACA side-to-side anastomosis.[9] This bypass technique was classified as in situ bypass or communicating bypass, and has been used most frequently in the recent literature.[1,19] However, its long-term results and complications remain unclear. We report a case of a de novo aneurysm arising at a site of A_3-A_3 anastomosis, treated successfully by a Y-shaped superficial temporal artery (STA) interposition graft bypass. We also discuss the underlying cause of aneurysm formation using computational fluid dynamics (CFD) technology.

Case Report

History

A 53-year-old woman first presented with a sudden onset of severe headache. Computed tomography showed subarachnoid hemorrhage with intracerebral hematoma in the right rectal gyrus (Fig. 1A). Digital subtraction angiography (DSA) showed a growing aneurysm of the proximal A_2 segment of the right ACA (Fig. 1B and C). The diagnosis was a dissecting aneurysm of the right A_2 segment. An A_3-A_3 side-to-side anastomosis was performed (Fig.

ABBREVIATIONS ACA = anterior cerebral artery; CFD = computational fluid dynamics; DSA = digital subtraction angiography; MCA = middle cerebral artery; STA = superficial temporal artery.
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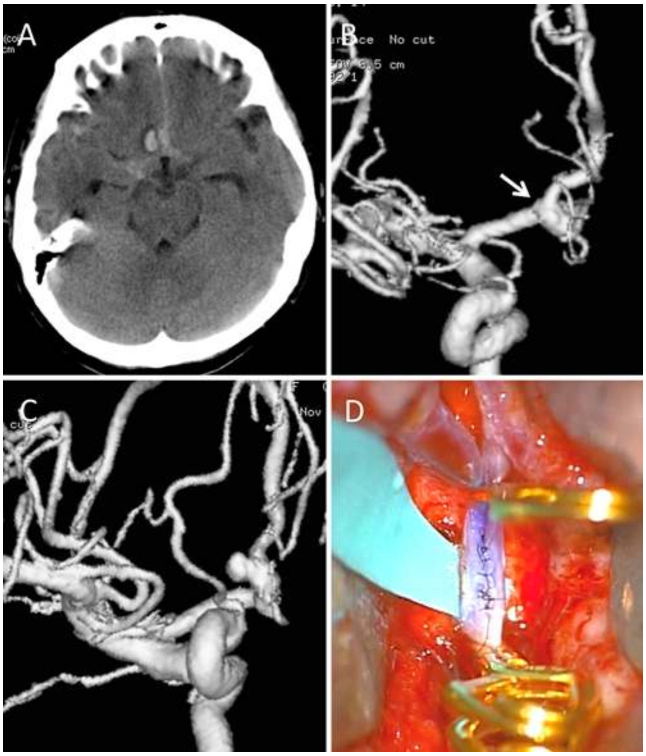

FIG. 1. A: Axial CT scan shows a subarachnoid hemorrhage with an intracerebral hematoma in the right rectal gyrus. **B:** Cerebral angiography shows the small bulge at the right proximal A_2 segment (*arrow*). **C:** Follow-up angiography 9 days after the onset shows growth of the aneurysm. **D:** Intraoperative photograph shows the A_3-A_3 bypass. Figure is available in color online only.

1D), and the aneurysm was trapped and resected to prevent rebleeding. The histological diagnosis was a dissecting aneurysm (data not shown). Postoperative angiography showed disappearance of the dissecting aneurysm and patency of the A_3-A_3 bypass (Fig. 2A). The patient recovered and was discharged without any neurological deficits. However, a de novo aneurysm was suspected at the site of the A_3-A_3 anastomosis by an annual MRI follow-up examination 44 months after surgery.

Examination

Aneurysm formation was not apparent on the first DS angiogram 14 days postoperatively (Fig. 2A). However, the existence of a small bulge was suspected on the second angiogram 6 months after surgery (Fig. 2B). This bulge apparently had grown to 5 mm in maximum diameter on the third angiogram 44 months postoperatively (Fig. 2C). A third DS angiogram showed that the blood flow from the left A_2 segment turned back to the right proximal A_2 segment, which hit against the front wall of the anastomosis site (Fig. 3A). Furthermore, a CFD study showed the localized region with high wall shear stress coincident with the pulsation in the front wall of the anastomosis site, where the aneurysm developed (Fig. 3B, Video 1).

VIDEO 1. Clip showing CFD study of the localized region with high wall shear stress (*red*) coincident with the pulsation in the front wall of the anastomosis site. Copyright Hidenori Endo. Published with permission. Click here to view.

Surgical obliteration of the growing aneurysm was scheduled to prevent possible risk for future rupture.

Operation

A curved bicoronal skin incision was made. On the right side, the skin incision was made along with the parietal branch of the right STA. The STA trunk and its branches (frontal and parietal) were dissected carefully as the skin flap was retracted. After removing the periadventitial tissue, a Y-shaped STA graft was harvested and immediately flushed with heparinized saline. Bifrontal craniotomy was then performed. The extent of the craniotomy was larger than during the first surgery so as to provide a wider opening of the interhemispheric fissure. After sharp dissection of the interhemispheric fissure, we exposed the aneurysm and the bilateral ACAs (Fig. 4A). The aneurysm developed in the front wall of the anastomosis site, and projected to

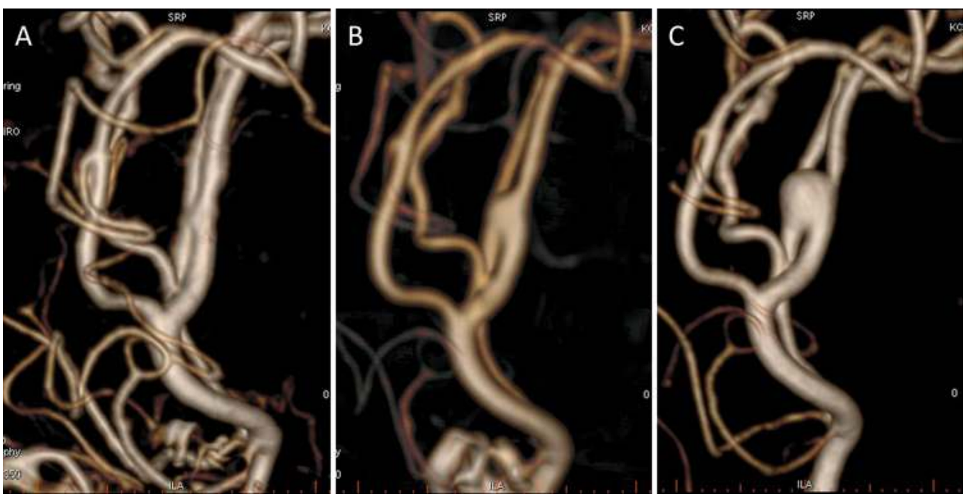

FIG. 2. A: Cerebral angiography obtained 14 days after surgery shows the disappearance of the right A_2 dissecting aneurysm and patency of the bypass. **B:** Follow-up angiography obtained 6 months after surgery shows a small bulge at the site of anastomosis. **C:** Follow-up angiography obtained 44 months postoperatively shows that the bulge had grown up to 5 mm in maximum diameter. Figure is available in color online only.

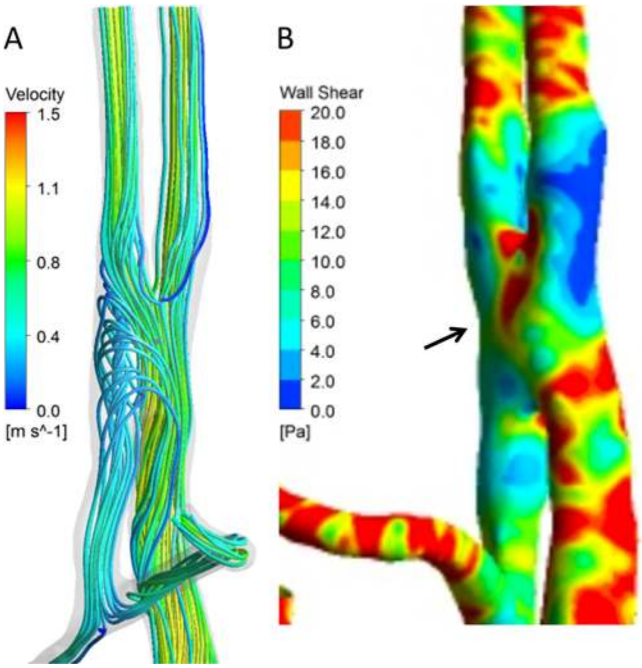

FIG. 3. A: CFD study performed before the aneurysm formation shows the hairpin-shaped blood stream at the site of anastomosis. **B:** CFD study shows the localized region with high wall shear stress coincident with the pulsation in the front wall of the anastomosis site (*arrow*). Figure is available in color online only.

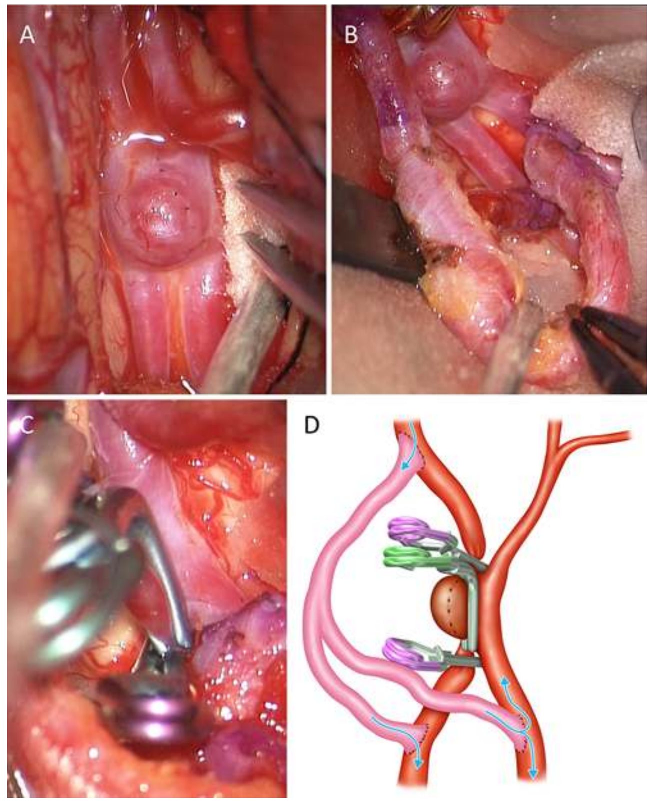

FIG. 4. A: Intraoperative photograph shows the aneurysm developed in the front wall of the anastomosis site, and projects to the anterosuperior direction. Sutures had been placed in the anterior wall of the aneurysm during the previous surgery. **B:** Intraoperative photograph shows completion of the bypass using a Y-shaped STA graft. **C:** Intraoperative photograph shows the completed trapping of the aneurysm. **D:** Operative illustration shows the site of the anastomosis and clip application in the second surgery. Copyright Hidenori Endo (panel D). Published with permission. Figure is available in color online only.

the anterosuperior direction. Sutures had been placed in the anterior wall of the aneurysm during the previous surgery. The aneurysm appeared similar to the usual saccular aneurysms.

The frontal and parietal branches of the STA graft were anastomosed to the left and right A_3 segments (distal to the aneurysm) in an end-to-side manner, respectively. The occluding time for anastomosis was 25 and 20 minutes, respectively. The STA trunk then was anastomosed to the left A_2 segment (proximal to the aneurysm) in an end-to-side manner, with a 28-minute temporary occlusion (Fig. 4B). After completion of the anastomosis, the aneurysm was trapped along with the left ACA by an aneurysm clip. Then, a booster clip was applied to occlude the aneurysm to reconstruct the right ACA (Fig. 4C and D). Indocyanine green video angiography showed patency of the Y-shaped STA graft and occlusion of the aneurysm.

Postoperative Course

Postoperative diffusion-weighted MRI on the day after surgery revealed no ischemic or hemorrhagic complications (Fig. 5A). Angiography 6 months after surgery revealed disappearance of the aneurysm and patency of the Y-shaped STA graft (Fig. 5B and C). The postoperative course was uneventful, and the patient was discharged without any neurological deterioration.

Discussion

To the best of our knowledge, this is the first report of a de novo aneurysm that developed at the site of an ACA-ACA side-to-side anastomosis. A CFD study suggested the association between the hemodynamic stress and aneurysm formation. The aneurysm was obliterated successfully with reconstruction of both ACAs by a Y-shaped STA interposition graft bypass.

Mechanisms for De Novo Aneurysm Formation After Bypass Surgery

A total of 16 cases with de novo aneurysm formation at the site of anastomosis after STA–middle cerebral artery (MCA) bypass have been reported in the literature.[4–7,10–13,15,17,18,20,21,24] The interval between bypass surgery and detection of the aneurysm ranged from 2 weeks to 27 years.[7,20] Nine of these 16 cases were detected at the time of rupture,[4,5,7,10,11,17,18,21] and these hemorrhagic events resulted in a poor or even fatal clinical outcome.[7,13] Thus, long-term follow-up is necessary to avoid this fatal complication, although its incidence is low. Mechanical arterial wall injuries, such as intraoperative vascular manipulation or excessive adventitial stripping, might be an underlying cause of aneurysm formation.[13] In addition to these factors, recent studies have suggested that the increased hemodynamic stress leads to aneurysm formation because de novo aneurysms can arise from the MCA wall in an artificial T-shaped vasculature that is subjected to jet stream force

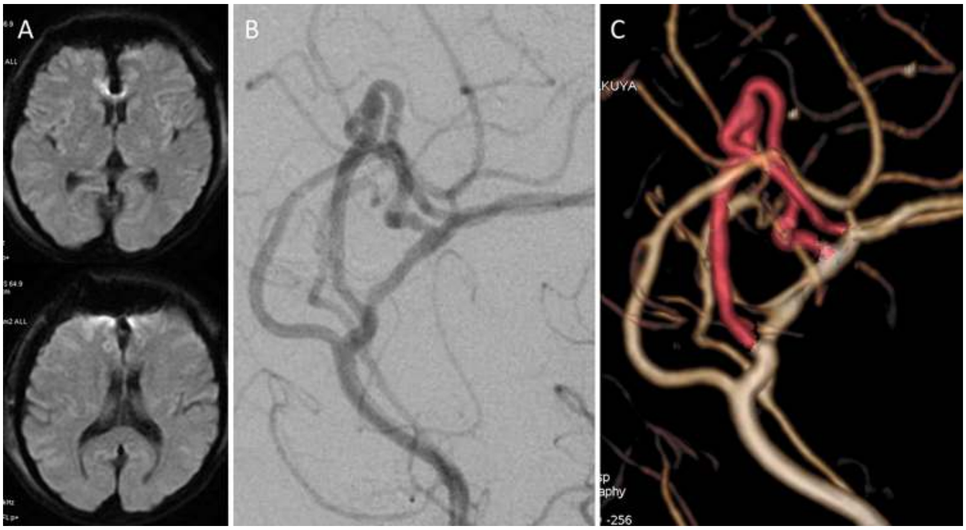

FIG. 5. A: Postoperative axial diffusion-weighted imaging obtained the day after surgery reveals no ischemic complications. **B**: Postoperative angiography 6 months after surgery shows obliteration of the aneurysm and patency of the Y-shaped STA graft. **C:** Three-dimensional angiography shows patency of the graft (*pink*). Figure is available in color online only.

from the STA.[11,21,24] Based on this speculation, postoperative long-term control of blood pressure is important to reduce this hemodynamic stress.[2,24] In our case, hairpin-shaped blood flow was detected at the site of anastomosis in the DSA performed before aneurysm formation. This bloodstream might induce a localized region with high wall shear stress coincident with the pulsation in the front wall of the anastomosis site, where the aneurysm developed. These data suggested that the hemodynamic stress had a positive association with the aneurysm formation. Another possible explanation for aneurysm formation is inherent vascular fragility. It has been considered that patients with arterial dissection could have a constitutional, genetically determined weakness of the vessel wall and that environmental factors, such as acute infection or minor trauma, could act as triggers.[3,22] The history of an intracranial dissecting aneurysm might have some association with the de novo aneurysm formation at the site of anastomosis, although genetic factors were not investigated.

Revascularization for ACA

Clipping,[17,18,20,21] trapping with bypass,[10] and wrapping[12,15] are used to treat a de novo aneurysm at the site of anastomosis. We considered the possibility that the whole vascular wall around the aneurysm was under a pathological condition, and the necessity to exclude this pathological part from the blood circulation as much as possible. One procedure to achieve this was simply to clip the aneurysm. However, clipping might cause a stenoocclusive complication because the aneurysm involved both ACAs. Thus, we performed revascularization of both ACAs using a Y-shaped STA interposition graft. We then performed trapping of the left ACA along with the aneurysm. The Y-shaped STA graft supplied the blood flow to the bilateral ACAs: unidirectional flow in the left ACA and bidirectional flow in the right ACA, without ischemic complications. Another option to secure the aneurysm would be an endovascular approach. Stent-assisted coil embolization or flow diversion would be the potential solution. However, this aneurysm developed in the distal ACA, which was disadvantageous for an endovascular approach.

Several techniques have been reported for revascularization of bilateral ACAs. Sekhar et al.[23] used a radial artery graft from the MCA or STA to the A_4 segment followed by A_4-A_4 side-to-side bypass, or a "Y" radial artery graft from the MCA or STA to both A_4 segments. Inoue et al.[8] reported a similar technique using a radial artery graft from the STA to the A_3 segment followed by A_3-A_3 side-to-side anastomosis. Mirzadeh et al.[14] reported the double reimplantation technique using a radial artery graft, which can connect the A_2 segment to bilateral A_3 segments. In contrast to these attractive but complicated techniques, Mura et al.[16] reported a simple technique using a Y-shaped STA interposition graft, which is similar to the technique used in the present case. They performed revascularization for both pericallosal arteries with 3 end-to-end anastomoses during resection of the malignant meningioma with encasement of both pericallosal arteries.[16] The use of a Y-shaped STA graft is advantageous because it can be harvested easily and quickly in the same surgical field, it needed only 3 sites of simple anastomosis, and the diameter was similar to that of the ACA.[16] The disadvantage of the STA graft is delayed wound healing or necrosis.[16] Furthermore, the STA can be a single trunk without the appropriate branch for a Y-shaped graft. It is necessary to harvest other grafts for this situation, such as the radial artery or saphenous vein. Preoperative assessment of the STA is necessary to determine whether the STA is appropriate as a graft.

Conclusions

De novo aneurysms rarely develop at the site of an ACA-ACA side-to-side anastomosis. A Y-shaped STA interposition graft is a useful option to treat this de novo aneurysm. Hemodynamic stress might be an underlying cause of aneurysm formation. Long-term follow-up is necessary to detect this rare complication after ACA-ACA anastomosis.

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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: H Endo. Acquisition of data: H Endo, Sugiyama. Analysis and interpretation of data: H Endo, Sugiyama. Drafting the article: H Endo, Sugiyama. Critically revising the article: T Endo. Reviewed submitted version of manuscript: H Endo, T Endo, Fujimura, Shimizu, Tominaga. Approved the final version of the manuscript on behalf of all authors: H Endo. Study supervision: Tominaga.

Supplemental Information

Videos

Video 1. https://vimeo.com/230006445.

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Methods. https://thejns.org/doi/suppl/10.3171/2017.6.JNS17931.

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