

Arterial Bypass Surgery Using a Spontaneously Formed “Bonnet” Superficial Temporal Artery in a Patient With Symptomatic Common Carotid Artery Occlusion: Case Report

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BACKGROUND: Common carotid artery (CCA) occlusive disease may cause hemodynamic cerebral ischemia resulting in the development of ischemic symptoms. The blood flow in the superficial temporal artery (STA) ipsilateral to the occluded CCA is usually poor, which limits its use as a donor artery for extracranial-intracranial arterial bypass surgery.

CLINICAL PRESENTATION: Despite antiplatelet therapy, recurrent transient ischemic attacks manifesting as motor aphasia developed in a 72-year-old man. Neuroradiological imaging revealed misery perfusion in the bilateral cerebral hemispheres caused by left CCA occlusion and right internal carotid artery occlusion. Blood flow from the STA contralateral to the occluded CCA perfused the ipsilateral STA over the midline in a retrograde fashion.

INTERVENTION: After confirming the direction and the pressure of the blood flow in the spontaneously formed “bonnet” STA, the STA was anastomosed to a cortical artery in the symptomatic frontal lobe so that blood flow in the ipsilateral STA was supplied from the contralateral STA. The procedure was accomplished without difficulty, and no further ischemic symptoms developed after surgery. Postoperative cerebral angiography demonstrated an increase in collateral flow to the anastomosed bonnet STA and perfusion to an entire territory of the upper trunk of the symptomatic middle cerebral artery via the anastomosis.

CONCLUSION: This case suggests that arterial bypass surgery can be performed using a spontaneously formed bonnet STA as a donor in a patient with symptomatic CCA occlusion.

KEY WORDS: Arterial bypass, Common carotid artery occlusion, Donor artery

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Extracranial-intracranial (EC-IC) arterial bypass surgery involves an anastomosis of the superficial temporal artery (STA) with the middle cerebral artery (MCA) to bypass atherosclerotic stenoses or occlusions of the internal carotid artery (ICA) or MCA. Although one international randomized trial reported that this procedure was ineffective in preventing stroke recurrence,¹ several investigators suggest that EC-IC bypass surgery may be beneficial for patients with hemodynamic cerebral ischemia,²⁻⁴ characterized by elevated oxygen extraction fraction or reduced cerebrovascular reactivity to acetazolamide.⁵⁻⁸

ABBREVIATIONS: CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotid artery; EC-IC, extracranial-intracranial; MCA, middle cerebral artery; STA, superficial temporal artery

Common carotid artery (CCA) occlusive disease may also cause hemodynamic cerebral ischemia, resulting in the development of ischemic symptoms.^{9,10} Further, blood flow in the STA ipsilateral to the occluded CCA is usually poor, meaning that the artery cannot be used as a donor artery in EC-IC bypass surgery. Thus, various complicated strategies have been used for revascularization of the ipsilateral MCA territory.¹¹⁻²¹

The “bonnet” bypass is a variant of the EC-IC bypass that has been used in the context of tumor surgery involving the cranial base.^{22,23} The word “bonnet” describes the coronal section angiographic image of an interposed vascular graft running in the subcutaneous tissue from the contralateral donor vessel (eg, branch of the STA), over the head, to the ipsilateral recipient vessel (eg, cortical branch of the MCA).¹⁰

In this report, we describe a patient with recurrent ischemic attacks and hemodynamic cerebral ischemia caused by CCA occlusion. In this patient, blood flow from the STA contralateral to the occluded CCA perfused the ipsilateral STA over the midline of the head in a retrograde fashion, and arterial bypass surgery was accomplished using the spontaneously formed bonnet STA as a donor.

CASE REPORT

A 72-year-old man with hypertension presented with a transient ischemic attack manifesting as motor aphasia that lasted for several minutes, and antiplatelet medication (clopidogrel 75 mg/d) was initiated at a local hospital. However, the same symptoms frequently recurred over the 2 months since initial symptom onset, and the patient was admitted to our department for specialized care and further evaluation.

On admission, a neurological examination revealed no abnormal signs. Magnetic resonance imaging of the head revealed ischemic lesions in the deep white matter in the bilateral cerebral hemispheres. Cerebral angiography with arterial catheterization demonstrated occlusion of the left CCA proximal to its bifurcation (Figure 1A). Although collateral circulation via branches originating from the left vertebral artery perfused the left cervical external carotid artery (ECA), blood flow from the collateral pathways to the left STA was poor (Figure 1B). The right ICA was occluded at its origin, and the blood flow from the right STA perfused the left STA over the midline of the head in a retrograde fashion (Figure 1C). The right vertebral artery perfused the bilateral middle and anterior cerebral artery territories via the bilateral posterior communicating arteries (Figure 1D). Positron emission tomography using ^{15}O -labeled O_2 inhalation³ revealed an oxygen extraction fraction higher than the mean + 2 standard deviations of healthy volunteers in the bilateral frontal lobes (Table, Figure 2). Quantitative brain perfusion single-photon emission computed tomography²⁴ showed cerebral blood flow and cerebrovascular reactivity to acetazolamide lower than the mean - 2 standard deviations of healthy volunteers in the bilateral anterior cerebral artery and MCA territories (Table, Figure 3). Based on these results, the bilateral cerebral hemispheres were considered to be in a state of misery perfusion, and arterial bypass surgery was performed in the symptomatic cerebral hemisphere.

A linear skin incision was performed along the left STA with the patient under general anesthesia (Figure 4A). After exposing the left STA to a length of 3 cm, retrograde flow of arterial blood in the left STA toward the origin of the left ECA was confirmed using a micro-Doppler flowmeter. Next, after completion of exposure of the left STA (10-cm length), 1 branch originating from the STA was identified, and a vascular catheter connected to a pressure transducer was inserted in the branch. This system was used to measure blood pressure in the STA when the STA segment proximal (near the origin of the left ECA) or distal (near the right STA) to the junction of the branch was temporarily occluded. A vascular catheter inserted in the radial artery was also used to measure systemic blood pressure during temporary occlusion of the

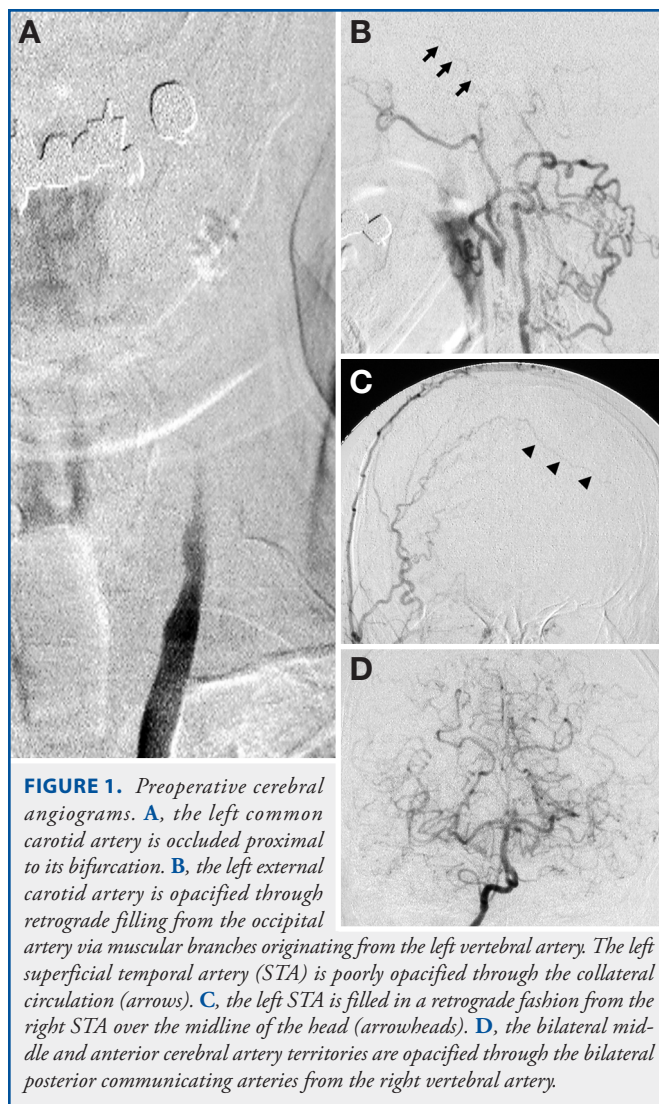


FIGURE 1. Preoperative cerebral angiograms. **A**, the left common carotid artery is occluded proximal to its bifurcation. **B**, the left external carotid artery is opacified through retrograde filling from the occipital artery via muscular branches originating from the left vertebral artery. The left superficial temporal artery (STA) is poorly opacified through the collateral circulation (arrows). **C**, the left STA is filled in a retrograde fashion from the right STA over the midline of the head (arrowheads). **D**, the bilateral middle and anterior cerebral artery territories are opacified through the bilateral posterior communicating arteries from the right vertebral artery.

STA; the mean blood pressure of the STA during temporary occlusion of the proximal or distal STA was 91% or 35% of systemic blood pressure, respectively. The bonnet STA was deemed suitable for use as a donor artery. A left frontotemporal craniotomy was performed, and the bonnet STA was anastomosed to a cortical artery in the frontal lobe so that blood flow in the left STA was supplied from the right STA (Figure 4B). The operation was performed without difficulty, and the postoperative course was uneventful. No further ischemic symptoms developed after surgery.

Cerebral angiography 4 months after surgery demonstrated an increase in collateral flow to the anastomosed bonnet STA and perfusion to an entire territory of the upper trunk of the left MCA via the anastomosis (Figure 5). Quantitative brain perfusion single-photon emission computed tomography performed at the same time showed improvement in the cerebral blood flow and cerebrovascular reactivity to acetazolamide in the bilateral anterior and MCA territories (Table, Figure 3).

TABLE. Quantitative Values of Cerebral Blood Flow and Metabolism Obtained Using Positron Emission Tomography and Single-Photon Emission Computed Tomography^a

	Patient				Healthy Volunteers ^{3,24}		
	Left Hemisphere		Right Hemisphere		Mean ± SD	Mean + 2 SDs	Mean - 2 SDs
	Before Surgery	After Surgery	Before Surgery	After Surgery			
PET-OEF	0.55		0.53		0.44 ± 0.04 (n = 20)	0.52	
SPECT-CBF (mL/100 g/min)	23.4	29.6	22.9	29.5	35.9 ± 4.4 (n = 20)		27.1
SPECT-CVR (%)	-13.1	+22.4	-8.6	+5.8	+36.8 ± 9.2 (n = 20)		+18.4

^a SDs, standard deviations; PET, positron emission tomography; OEF, oxygen extraction fraction; SPECT, single-photon emission computed tomography; CBF, cerebral blood flow; CVR, cerebrovascular reactivity.

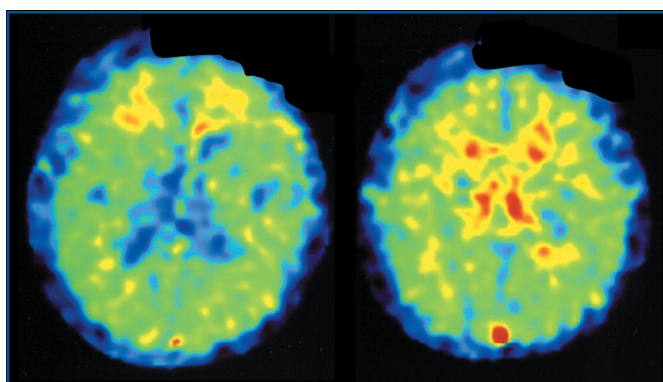


FIGURE 2. Positron emission tomography images at the level of body of the lateral ventricle (left) and the centrum semiovale (right) before surgery showing increased oxygen extraction fraction in the bilateral frontal lobes, especially in the white matter.

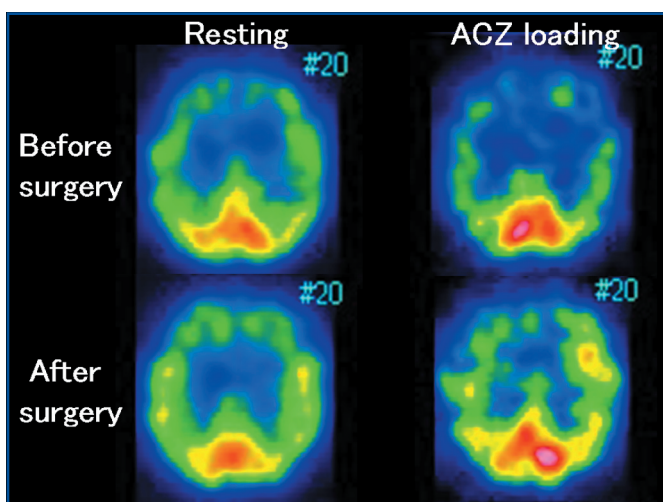


FIGURE 3. Preoperative brain perfusion single-photon emission computed tomography (upper row) showing reduced cerebral blood flow (left) and reduced cerebrovascular reactivity to acetazolamide (ACZ) (right) in the bilateral anterior and middle cerebral artery territories. The cerebral blood flow and cerebrovascular reactivity to acetazolamide are improved after surgery (lower row).

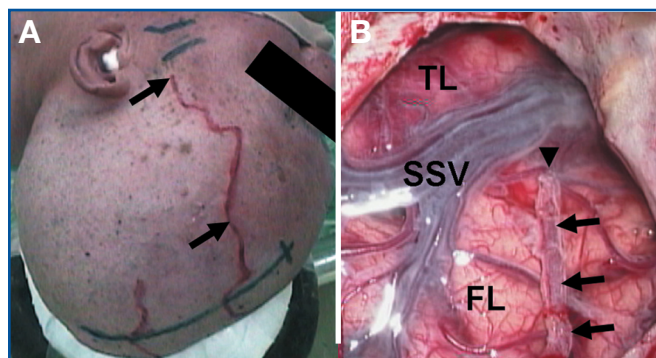


FIGURE 4. Intraoperative findings. **A**, the red line near the face indicates the superficial temporal artery (STA) running in the scalp. A skin incision is performed along the STA between the 2 arrows. **B**, the left STA (arrows) is anastomosed to a cortical artery in the left frontal lobe (arrowhead) so that blood flow in the left STA was supplied in a retrograde fashion. TL, temporal lobe; FL, frontal lobe; SSV, superficial sylvian veins.

DISCUSSION

CCA occlusion is generally classified into 2 types, as described by Riles et al.¹⁹ Type 1 involves occlusion of the CCA with patent ICA and/or ECA and includes 3 subtypes: type 1A, patent ICA and ECA; type 1B, patent ECA with occluded ICA; and type 1C, patent ICA with occluded ECA. Type 2 involves complete occlusion of the CCA, ICA, and ECA. Various types of bypasses have been also reported, including (1) the subclavian artery to the ICA^{12,14,16,18-20}; (2) the subclavian artery to the ECA, with or without an STA-MCA anastomosis^{11,15}; (3) the subclavian artery to the MCA^{14,21}; (4) the contralateral ECA to the ipsilateral MCA⁶; and (5) the contralateral ECA to the ipsilateral ECA.¹⁷ In all procedures described, a free graft, such as a saphenous vein graft, radial artery graft, and prosthetic graft, is required. By contrast, Kobayashi et al²⁵ reported using a transverse cervical artery bypass procedure that uses a pedicle graft to the ipsilateral ECA rather than a free graft. This case consisted of a type 1B CCA occlusion, and anastomoses in the cervical and intracranial regions were required to enable application of any of the procedures described.

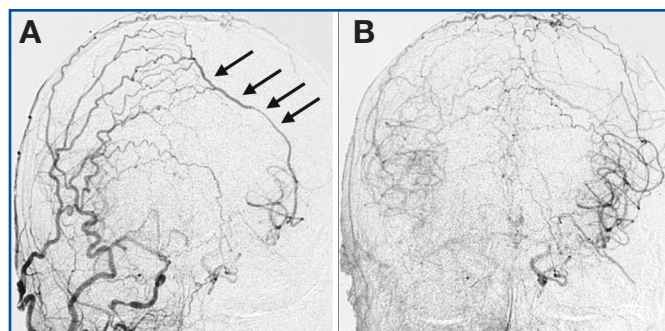


FIGURE 5. Postoperative right external carotid artery (ECA) angiograms revealing an increase in collateral flow from branches of the ECA to the anastomosed bonnet superficial temporal artery (arrows) and perfusion to an entire territory of the upper trunk of the left middle cerebral artery via the anastomosis.

Although a bonnet bypass (contralateral STA-interposed vascular graft-ipsilateral cortical branch of the MCA) has been performed in patients with a cranial base tumor who required surgical occlusion of the ipsilateral CCA,^{22,23} the bypass has also been recently applied for atherosclerotic CCA occlusion with symptomatic hemodynamic cerebral ischemia.¹⁰ The bonnet bypass is less invasive than other types of bypasses for type 1B CCA occlusion¹⁰ and is applicable to any type of CCA occlusion. In our case, the ipsilateral STA to the occluded CCA was perfused in a retrograde fashion by the STA contralateral over the midline of the head, and arterial bypass surgery was accomplished using the spontaneously formed bonnet STA as a donor. The complexity of this method was comparable to that of a standard STA-MCA anastomosis.

Arteries feeding the scalp, including the STA, commonly anastomose with contralateral scalp arteries.²⁶ Thus, as ipsilateral ECA blood pressure decreases gradually over time secondary to progressive chronic occlusion of the ipsilateral CCA, a scalp artery anastomosis may develop, and a bonnet STA may form spontaneously. Although the incidence of spontaneous bonnet STA formation remains unknown, we recommend cerebral angiography to confirm the absence or presence of the bonnet STA in patients with symptomatic CCA occlusion who require cerebral revascularization. We also recommend measurement of the direction and pressure of blood flow in the bonnet STA to confirm suitability for use as a donor artery. Based on the current data, we propose that a mean blood pressure in the STA more than 90% of the systemic blood pressure indicates that the STA is suitable for use as a donor artery. When the bonnet STA is not suitable for use as a donor artery, other complicated surgical strategies, such as revascularization of the ipsilateral ECA with an ipsilateral STA-MCA anastomosis, should be considered.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

Revascularization surgery in the setting of multiple occluded arteries is often extremely challenging. The case report described here by Aso et al provides a new option for augmentation revascularization of the ipsilateral hemisphere when the common carotid artery is occluded. Other surgeons considering this technique would be well advised to follow the authors' technique of pressure measurement to confirm adequacy of the donor artery before performing an anastomosis.

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The authors described a bypass surgery using a spontaneously formed "bonnet" superficial temporal artery (STA) as a donor artery. Among various vessels to be used as a donor artery, the authors described the use of a unique option, and this is an interesting case report worth read-

ing. The use of a spontaneously formed bonnet STA allowed the authors to perform the revascularization surgery in a patient with the symptomatic common carotid artery occlusion. The spontaneous bypass from the right to left STA might be a rare occurrence. Based on preoperative angiograms, the left occipital artery (OA) via the left vertebral artery was visible. In some cases, the OA can be used as a donor artery for middle cerebral artery revascularization.¹ This method is a simple and effective for extracranial-intracranial bypass surgery. Therefore, in this case report, it is possible that using the OA as a donor artery for anastomosis is another option.

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