Use of Superior Thyroid Artery as a Donor Vessel in Extracranial-Intracranial Revascularization Procedures: A Novel Technique

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Abstract

Objective To describe the use of the superior thyroid artery as a donor vessel in extracranial-intracranial (EC-IC) revascularization when a "low-flow" bypass is required and the superficial temporal artery is not available.
Design Case report.
Setting University hospital.
Participants Four cases.
Main Outcome Measures Postoperative course after EC-IC bypass surgery.
Results In case 1, the parent vessel was occluded postoperatively. The radial bypass was sufficient to replace the internal carotid artery (ICA) flow, and a prophylactic was turned into a definitive bypass. In case 2, the superior thyroid artery was used because the radial artery was not long enough to reach the external carotid artery. The recipient vessel was modified from the middle cerebral artery to the ophthalmic segment of the ICA. In case 3, the graft was occluded after surgery because of carotid artery reconstruction. In case 4, after surgery/radiotherapy for meningioma, the patient developed wound dehiscence and was reoperated for bypass occlusion. The graft was weak and bled intraoperatively, without infarction. The three first patients are intact, and the fourth remains disabled (Glasgow Outcome Scale: 3; Rankin Scale: 5).
Conclusion The superior thyroid artery was adequate for proximal anastomosis in EC-IC procedures in the situations described.

Keywords
- cerebral revascularization
- EC-IC arterial bypass
- brain/blood supply
- surgical procedures
- operative

Introduction

Revascularization is currently recognized as a favorable treatment choice for complex intracranial lesions. In this context, extracranial-intracranial (EC-IC) bypass is usually performed for increase in or replacement of cerebral blood supply, especially in the presence of complex aneurysms or in skull base tumor surgery involving vessel sacrifice,[1–5] a situation

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associated with risk of ischemic complications in ~ 20% of patients.[6] Prophylactic bypass may also be indicated in certain groups, such as young patients, or when the risk of delayed ischemia is suspected, even following a tolerated balloon test occlusion (BTO). Normally, the prophylactic bypass is done with the superficial temporal artery (STA), but when the STA is not available or is unsuitable, the radial artery (RA) can be used as a graft vessel.

Several bypass options are available. Their choice is usually based on factors such as size of the recipient vessel, desired amount of blood flow, and revascularization site, among others.[6] In theory, cerebral bypass can be categorized as low flow (STA 15–25 mL/minute), medium flow (RA or interposition artery 40–70 mL/minute), and high flow (great saphenous vein 70–140 mL/minute).[7] However, it is now accepted that blood flow can be highly variable in the donor artery.[8]

When a "medium-flow" bypass is required, RA graft is the choice, and the recipient vessel is the external carotid artery (ECA). When a "low-flow" bypass is required and the STA is not available as an alternative, our group has used the superior thyroid artery (SThA) as the donor vessel, combined with a RA graft. In the present study, we describe three cases in which a SThA-RA-middle cerebral artery (MCA) bypass was used, and one case in which a SThA-RA-internal carotid artery (ICA) ophthalmic segment bypass was performed. We also present our protocol for the management of complex vascular lesions for which a SThA bypass was indicated.

Patients and Methods

The decision to use the SThA in revascularization procedures was made by the treating physician based on the level of blood flow required for a specific patient, the absence of a suitable STA, and the need for intraoperative modification of the surgical plan because of insufficient length of the RA graft. All patients provided consent for use and publication of data and images.

Superior Thyroid Artery

The SThA is the first branch stemming from the ECA. It arises just below the greater cornu of the hyoid bone. Through most of its course, it occupies the superior carotid triangle. It moves through the omohyoid, sternothyroid, and sternohyoid muscles, reaching the upper and front part of the thyroid body, where it also ends. The SThA has the following branches: infrahyoid, middle sternocleidomastoid, superior laryngeal, and cricothyroid arteries.

Surgical Technique

A cranial anastomosis is performed first. In our series, the MCA was the recipient artery in three cases and the ICA in one case. The exposure of the bifurcation of the common carotid artery, craniotomy with fronto-orbital branch of the facial nerve,[9] subzygomatic tunnel preparation, preparation of the RA graft, and intracranial exposure were performed as previously described.[10] After that, an end-to-end anastomosis was made between the SThA and the RA graft. The graft was prepared by removing the adventitia with care. A temporary clip is positioned in the proximal portion of the SThA, which is sectioned and anastomosed to the RA with a mono-nylon 8–0 or 9–0 suture. Before closing the last knot, the distal clips are removed to backflow the eventual air embolism.[11,12]

Then the clip in the SThA is removed and the flow is completed in the bypass. Graft perfusion can be determined intraoperatively by the use of indocyanine green videoangiography and by a Doppler flowmeter device. The palpation of the graft must not be used as a reliable sign of permeability.

At the closure stage, once the temporalis muscle covers the graft, the risk of injury of the graft at the entry point in the

Table 1 Description of patients undergoing revascularization with superior thyroid artery

Patient no./Sex	Age, y	Lesion	Patency	Complications	Postoperative outcome
1/M	47	Giant aneurysm of the ophthalmic artery	Yes	Asymptomatic occlusion of the ICA	Intact
2/F	52	Fusiform aneurysm of the ICA	Yes	Thrombus inside MCA; removal of thrombus and bypass using ICA as recipient vessel	Intact
3/F	61	Giant fusiform aneurysm of the ICA	Yes, with late occlusion	None	Intact
4/F	18	Giant anterior clinoid meningioma (previously irradiated)	Yes, occluded in second surgery	Transient hypoperfusion with improvement of postoperative infection	Neurologic decline due to underlying pathology and meningitis

Abbreviations: ICA, internal carotid artery; MCA, middle cerebral artery.

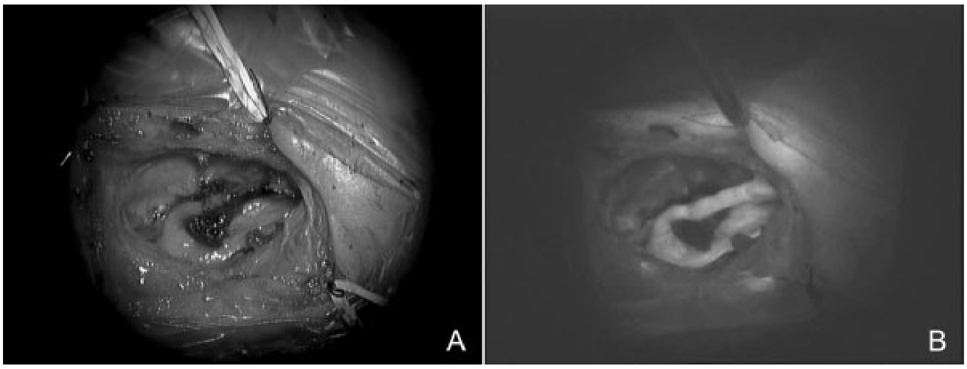

Fig. 1 (a) End-to-end anastomosis between the superior thyroid artery and the radial artery graft. (b) indocyanine green–enhanced image obtained during the procedure.

skull is low. Hemostasis must be thoroughly checked to avoid postsurgical hematomas.

Results

Of a series of 59 patients with 66 revascularization procedures performed by the senior author (J.M.) between 2005 and 2013 for the management of complex aneurysms, skull base tumors, and acute or chronic ischemia, the SThA was chosen for proximal anastomosis of the RA graft in four cases: (1) two cases due to absence of a suitable STA; (2) one patient who did not have the STA due to previous surgery and radiotherapy to treat a meningioma; and (3) one patient with a relatively short RA that could not be anastomosed to the ECA wall, making it more suitable for end-to-end anastomosis with the SThA.

►**Table 1** summarizes patient data and outcomes. ►**Fig. 1** shows the end-to-end anastomosis between the SThA and the RA graft in one of the cases. Case 1 (►**Fig. 2**) is the only one in which the parent vessel was occluded in the postoperative period. The radial bypass was sufficient to replace the ICA flow, and the prophylactic bypass was turned into a definitive

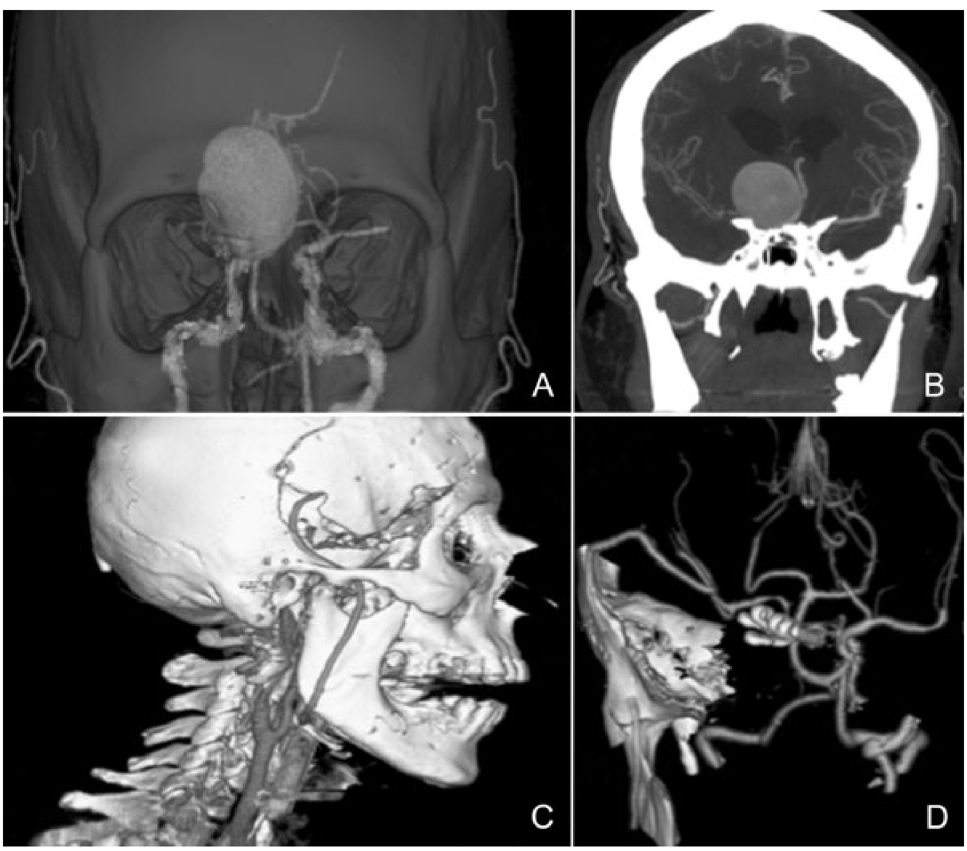

Fig. 2 Case 1. (A, B) Computed tomography angiography showing a giant aneurysm of the ophthalmic artery. (C) Position of the radial artery graft and anastomosis site. (D) Aneurysm treated with microclips.

bypass. In case 2 (►Fig. 3), the STA was used. The recipient vessel of the bypass was modified from the MCA to the ophthalmic segment of the ICA. In cases 3 and 4, the bypass was prophylactic. In case 3, the graft was occluded after the surgery because the carotid artery was reconstructed (►Fig. 4). In case 4, the patient showed postoperative neurologic decline due to underlying pathology and meningitis, requiring further intervention and occlusion of the bypass.

The three first patients are intact. The current status of case 4 is a Glasgow Outcome score of 3 and a Rankin score of 5. The patient was still disabled at the time this article was written.

No infarctions were present in this series. No thyroid symptoms were recorded after the surgery.

Discussion

In the present study, we described a novel EC-IC bypass technique using the SThA as the donor vessel. The proposed technique can be safely used in patients in whom the STA is too small or has been previously damaged. The main indication is for prophylactic bypass; however, the SThA can be used as a definitive bypass and also when the length of the radial graft is not sufficient to reach the ECA.

In case 1, the parent vessel was occluded in the postoperative period, but the radial bypass was sufficient to replace the ICA flow; the prophylactic bypass was therefore turned into a definitive bypass. This indicates that the SThA can provide a high flow when required, as previously pointed out.[8]

Case 2 was a very interesting one, in which a SThA-RA-ICA ophthalmic segment was performed, providing another indication for the SThA as a donor vessel. This occurred because the RA was not long enough to reach the ECA. In addition, an intraoperative thrombosis prevented the use of the MCA, originally planned as the recipient vessel, and the surgical plan was modified intraoperatively in favor of the ICA.

In case 3, the bypass was truly prophylactic. Despite the absence of a communicating vessel, the patient did not tolerate the BTO. The RA was used because the patient did not have a suitable STA. The carotid artery was successfully reconstructed, with spontaneous closure of the bypass and the absence of a clinical repercussion 1 month after the surgery.

The only severe complication occurred in case 4. This patient had a previous surgery and radiotherapy for a cavernous sinus meningioma. She developed wound dehiscence secondary to poor scarring and infection with meningitis, and required a new surgery and occlusion of the bypass. The graft was weak and bled during the procedure. The patient did not have infarction because normal circulation was preserved after total resection of the tumor. The bypass was prophylactic as well.

Another interesting indication is in cases in which the patient fails the BTO and an important external-internal carotid artery is present through the ophthalmic and/or the middle meningeal artery. The use of the usual medium- or high-flow bypass options has been challenged by some limitations including the possibility of hyperperfusion syndrome when the parent artery is not sacrificed. In three of the

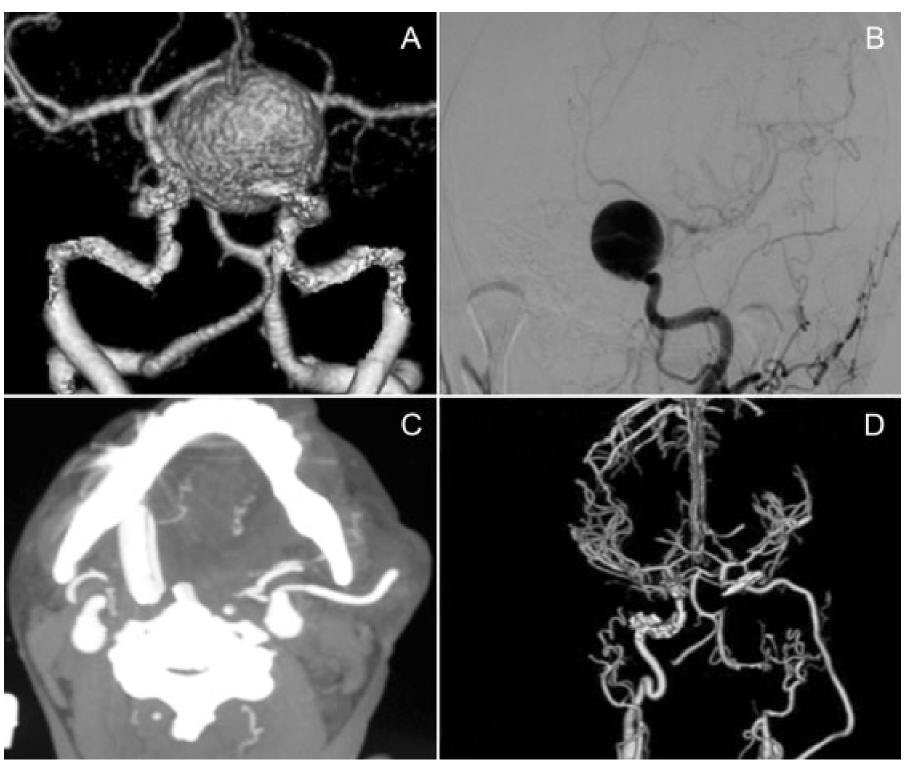

Fig. 3 Case 2. (A) Angiogram and (B) computed tomography angiography (CTA) showing a giant internal carotid artery aneurysm. (C) Clipped aneurysm and position of the radial graft bypass. (d) CTA showing the position of the bypass.

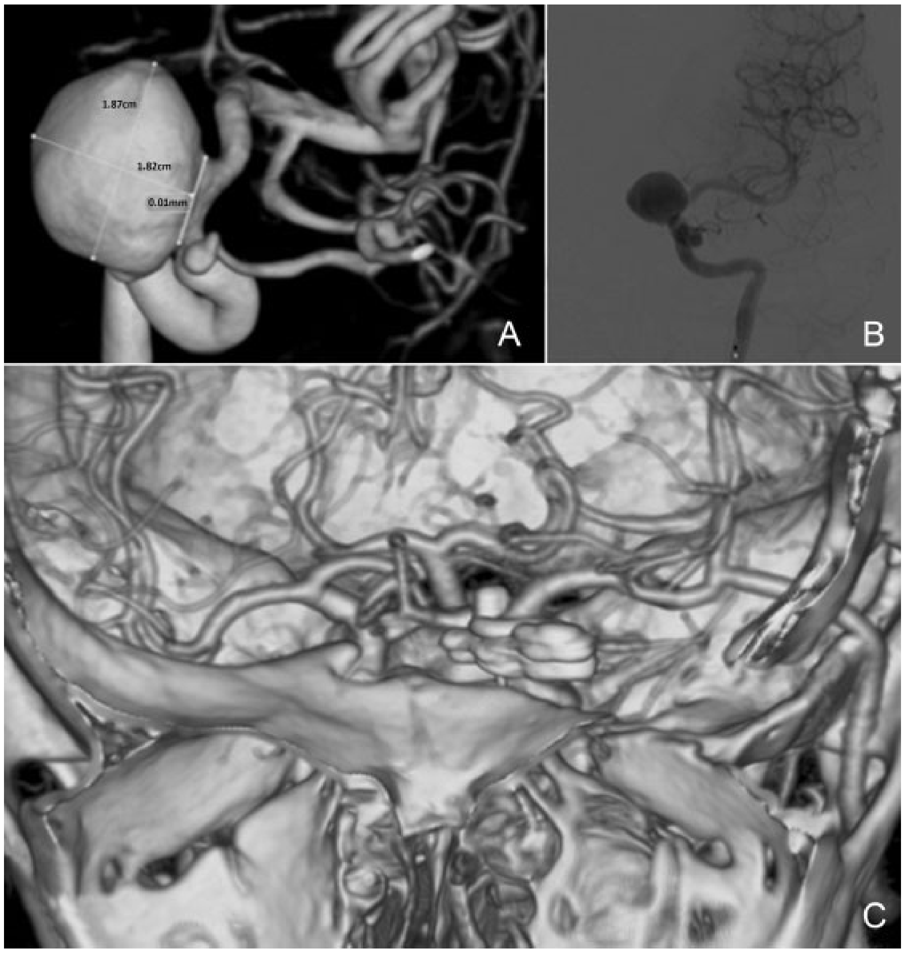

Fig. 4 Case 3. (A) angiogram and (B) computed tomography angiography showing a giant internal carotid artery aneurysm. (C) Clipped aneurysm and radial graft bypass. Despite the absence of a communicating vessel, this patient did not tolerate the balloon test occlusion. Because she did not have a suitable superficial temporal artery, the radial artery was used instead. The carotid artery was successfully reconstructed, with spontaneous closure of the bypass and absence of a clinical repercussion 1 month after the surgery.

cases described, although the patients did not tolerate the BTO, the surgeon considered the preservation of the carotid artery a priority and also highly feasible. Therefore, a "low-flow" bypass was planned in these cases. The SThA was chosen as the donor artery over other ECA branches (►**Fig. 5**) because, due to extensive collateral circulation within the thyroid gland, the direct ECA bypass would provide a medium-high flow that was considered to be unnecessary in the cases operated. Thus the solution used corresponds to an "STA-MCA-like flow" bypass when the STA is not available. In addition, although the facial artery could also have been used, as observed in free-flap reconstruction for head and neck cancer, the authors opted for the SThA because this artery technically facilitates grafting because it is located in the cervical region.

The results obtained with this new bypass were not unfavorable if compared with those described for other bypass techniques, with no ischemic complications. To the best of our knowledge, this is the first description of the treatment of complex aneurysms and/or tumors with a SThA bypass.

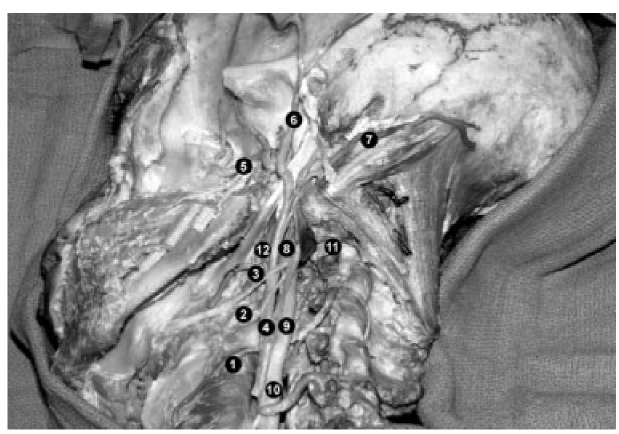

Fig. 5 Anatomical dissection showing the branches of the external carotid artery. (1) superior thyroid artery, (2) lingual artery, (3) facial artery (sectioned), (4) external carotid artery, (5) maxillary artery, (6) superficial temporal artery, (7) occipital artery, (8) ascending pharyngeal artery, (9) internal carotid artery, (10) common carotid artery, (11) vertebral artery, (12) ascending palatine artery.

Conclusion

The present case series shows that the SThA was adequate for proximal anastomosis in EC-IC procedures. Future studies with a larger number of patients, supported by intraoperative flow analysis, are warranted to validate and refine the indications for this bypass technique.

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

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