Case Report

Internal maxillary artery (IMax) – middle cerebral artery bypass in a patient with bilateral atherosclerotic carotid occlusion: A technical case report

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Since the first description of the possible utilization of the internal maxillary artery for bypass surgery, there are some reports of its use in aneurysm cases; however, there is no information about the possible advantages of this type of bypass for cerebral ischemic disease.

We present a 77-year-old man with a history of diabetes, hypertension, systemic atherosclerosis, and two acute myocardial infarctions with left hemiparesis. Imaging studies reported total occlusion of the right internal carotid artery and 75% occlusion on the left side, with an old opercular infarction and repeated transient ischemic attacks in the right middle cerebral artery territory despite medical treatment. After a consensus, we decided to perform a bypass from the internal maxillary artery to the M2 segment of the middle cerebral artery using a radial artery graft. After performing the proximal anastomosis, the calculated graft’s free flow was 216 ml/min. Subsequently, after completing the bypass, the patency was confirmed with fluorescein videoangiography and intraoperative Doppler. Postoperatively, imaging studies showed improvement in the perfusion values and the hemiparesis from 3/5 to 4+/5. The patient was discharged one week after the operation, with a modified Rankin scale of 1, without added deficits.

The use of revascularization techniques in steno-occlusive disease indicates a select group of patients that may benefit from this procedure. In addition, internal maxillary artery bypass has provided a safe option for large areas of ischemia that cannot be supplied with a superficial temporal artery - middle cerebral artery bypass.

Keywords Cerebral revascularization, Maxillary artery, Brain ischemia, Carotid artery stenoses, Carotid atherosclerosis, IMax bypass

INTRODUCTION

Yasargil was the first to report the use of an extracranial-intracranial (EC-IC) bypass in 1967 for cerebral atherosclerotic disease. After this report, flow augmen-
tation through an EC-IC bypass in occlusive disease increased until the results of the EC-IC Bypass Study, and the COSS (Carotid Occlusion Surgery Study) showed no apparent advantage of the procedure when compared with medical treatment. However, it has been demonstrated that a group of patients may still benefit from bypass if they meet criteria such as symptomatic steno-occlusive disease with an impaired perfusion image study with recurrent symptoms or stroke despite best medical treatment (BMT).

The Internal Maxillary artery (IMax) as a donor for EC-IC bypass was first described by Vrionis. After this report, many studies have reported variations of the surgical technique to reach the IMax, mainly for revascularization in aneurysm cases. However, to our knowledge, only one article uses IMax as a donor artery for occlusive disease. In these cases, the goal is to reestablish the regional blood flow and glucose metabolism and restore the functional state caused by the chronic ischemia favoring the regression of the hibernating brain.

This report shows the utility of the IMax - middle cerebral artery (MCA) bypass to increase the cerebral blood flow in a patient with bilateral internal carotid artery occlusion and repetitive transient ischemic attacks (TIAs) despite BMT.

**CASE DESCRIPTION**

**Presentation**

The Institutional Vascular Review Board approved this study. A 77-year-old man with a history of diabetes, hypertension, systemic atherosclerosis, and two acute myocardial infarctions sought medical attention due to repeated TIAs. The image workout showed almost total occlusion of the right internal carotid artery (ICA) with 75% occlusion of the left ICA and a minor stroke at the right MCA territory. Physical examination revealed a left hemiparesis of 3/5. The patient was classified as grade 2 of the modified Rankin scale (mRS). Medical treatment included antiplatelet drugs, control of glucose levels, blood pressure, and the use of statins. However, the patient continued with recurrent TIAs despite this treatment. Magnetic resonance imaging (MRI) with perfusion sequence showed an increase in the time to peak (TTP), mean transit time (MTT), and a decrease in the regional cerebral blood flow (rCBF) at the right ICA territory (Fig. 1A-D). A superficial temporal artery (STA) – MCA bypass was considered; however, this patient had a very small-caliber STA.

**Surgical approach (see supplementary Video 1)**

To identify the IMax, we used the technique described by Peto et al., consisting of a pterional approach with interfascial dissection of the temporal muscle (TM) and zygomatic osteotomy; the TM was cut, leaving a muscle cuff in the superior temporal line for the reconstruction. Next, the superior head of the lateral pterygoid muscle was identified and, if necessary, transected to discover the IMax. Afterward, a retrograde dissection was made to expose the whole pterygoid segment of the artery.

A radial artery graft (RAG) was obtained from the left side (after a negative Allen test) in a length of 12 cm. Then, a frontotemporal craniotomy was completed, with the temporal extension flush with the floor of the middle fossa. The Sylvian fissure was opened widely to identify M1–M2 segments of the MCA; the superior trunk was dissected and was left ready for distal anastomosis. Next, proximal and distal temporary clips were placed at the dissected segment of the IMax. The artery was divided after the alveolar nerve crossed it and was mobilized for an end-to-end anastomosis with the RAG. The anastomosis was completed with an 8-0 suture, using a separated suture technique; after the proximal anastomosis finished, the calculated graft’s free flow was 216 ml/min. Then, the anastomosis with the superior trunk of M2 was completed with a 10-0 suture with an interrupted suture technique. The temporary clips were released, and the patency was corroborated with fluorescein video angiography and intraoperative Doppler. The dura mater was closed, leaving a dural opening for the
Fig. 1. Imaging studies. (A-C) Preoperative time to peak (TTP), mean transit time (MTT), and regional cerebral blood volume (rCBV) perfusion MRI shows low perfusion in the right hemisphere. (D) MRI shows an area of a previous infarction in the right opercular area. (E-G) Postoperative TTP, MTT, and rCBV perfusion image without areas of hypoperfusion. (H) CT-angio shows the IMax-radial artery graft (RAG) end-to-end anastomosis (yellow arrow) and the end-to-side M2 anastomosis (white arrow). CT-angio, computed tomography angiography; IMax, internal maxillary artery.
RAG, and the rest of the surgical layers were closed and reconstructed as usual (Fig. 2).

**Postoperative course**

Postoperative computed tomography angiography (CT-Angio) showed patency of the bypass and adequate irrigation of the MCA territory. Diffusion-weighted imaging showed no areas of new ischemic events. Perfusion sequence showed a decrease in the TTP and MTT and an increase in the regional cerebral blood flow (rCBF) in the MCA territory, with hypoperfusion in the posterior cerebral artery (PCA) territory included the watershed area between MCA and PCA (Fig. 1E-H, Fig. 3). In addition, the patient's hemiparesis improved to 4+/5. The patient was discharged one week after the operation with an mRS of 1 without additional motor deficit to continue rehabilitation in a physical therapy facility.

*Fig. 2.* Illustrative case. (A) Surgical planning for a pterional and transzygomatic approach. (B and C) Incision and dissection of the radial artery. (D) IMax to radial artery graft end-to-end anastomosis. (E) Radial artery to M2 end-to-side anastomosis. (F) Intraoperative fluorescein video angiography shows the IMax-M2 anastomosis with radial artery graft (white arrows) with adequate perfusion of the cerebral hemisphere. IMax, internal maxillary artery

*Fig. 3.* Sagittal view shows the IMax-radial artery graft (RAG) end-to-end anastomosis (yellow arrow) and the end-to-side M2 anastomosis (white arrow). IMax, internal maxillary artery
DISCUSSION

Atherosclerosis of the ICA is a common pathology that leads to complete occlusion in 15,000-20,000 patients annually. These patients are still susceptible to TIA and may also experience an increased risk of cerebral hypoperfusion that could lead to brain atrophy, reduced corticospinal excitability, cognitive impairment, and dementia. The first response against the hypoperfusion is dilatation to the maximal capacity to increase cerebral perfusion; when this mechanism fails, the vascular insufficiency leads to an increase in oxygen extraction, and this compensatory mechanism reduces the reserve for additional functional demands, which leads to neurologic symptoms and a fluctuation between oligemia and ischemia.

Reynolds et al. classified cerebral hemodynamics failure into three stages: I, II, and III. Our patient presented stage III (true ischemia), meaning that cerebral perfusion pressure decreased below a critical point with a reduction of the volume and cerebral blood flow, prolonged TTP and MTT, and decreased brain metabolism, with an annual stroke rate of 31%. The indication for bypass in atherosclerosis and chronic ischemia is controversial, but when done under strict criteria, the goal is flow augmentation via a new donor artery that provides blood supply to the affected territory. The JET trial showed, for the first time, the preventive effect of EC-IC bypass on stroke recurrence, which has been proved in other series in selected patients.

Treatment strategy

The patient, in this case, as previously mentioned, continued with neurologic symptoms regardless of BMT, and the perfusion studies showed the whole right MCA territory with hypoperfusion that worsened with his daily activities, meaning that the patient alternated between oligemia and ischemia. So then, it was decided to perform the bypass in agreement with the Institutional Vascular Review Board.

The IMax was selected as a donor’s vessel because of the small size of the STA and the need to revascularize the whole MCA territory, meaning that the blood supply needed to be higher than 15–40 ml/100g/min. According to previous reports, IMax provides between 60–95 ml/min/100g. To localize the IMax artery, we selected the technique described by Peto et al. because of the short time needed to expose the artery. The radial artery was selected as a graft because it has some advantages; 1) more appropriate diameter similar to the M2 segment of the MCA, avoiding a type-2b error, 2) the lack of valves, 3) less possibility of kinking and 4), adequate length from the temporal fossa to the Sylvian fissure. In this case, the final length of the graft was 7 cm. We decided to perform the bypass to the superior trunk of M2 to prioritize the flow to the precentral and central arteries, which were the ones that irrigated the motor and supplementary motor cortex.

Cut flow calculation

In addition, the cut flow was calculated before discharge using transcranial Doppler measurements. The calculated flow at the RAG was 334 ml/min, and the flow of the MCA was 288 ml/ml. According to Jonathan and Charbel, these values provide a cut flow index of 0.86, meaning that the bypass has an 83.1% long-term patency rate.

To our knowledge, this is the first case published using an IMax bypass to treat a complex systemic steno-occlusive disease with improved perfusion parameters (TTP, MTT, and rCBF). Although we are waiting for new results of clinical trials such as Carotid and Middle cerebral artery Occlusion Surgery Study (CMOSS), this procedure has a physiologic and logical foundation, so it should not be discarded as an option for treatment.

CONCLUSIONS

The revascularization in steno-occlusive disease is indicated in carefully selected patients as the last bullet we can offer as treatment. The IMax bypass has proved...
to be a safe option in cases where total revascularization is needed and the ischemic area to treat is too large for the STA-MCA bypass.

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

Supplementary Video 1
The online-only data supplement is available with this article at https://doi.org/10.7461/jcen.2023.E2022.11.003.

REFERENCES


