

Clinical Article

Changes in Bypass Flow during Temporary Occlusion of Unused Branch of Superficial Temporal Artery

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Objective : Some neurosurgeons intentionally ligate the branches of the superficial temporal artery (STA) that are not used in standard STA-to-middle cerebral artery (MCA) anastomosis for the purpose of improving the flow rate in the bypass graft. We investigated changes in bypass flow during temporary occlusion of such unused branches of the STA.

Methods : Bypass blood flow was measured by a quantitative microvascular ultrasonic flow probe before and after temporary occlusion of branches of the STA that were not used for anastomosis. We performed measurements on twelve subjects and statistically assessed changes in flow. We also examined all the patients with digital subtraction angiography in order to observe any post-operative changes in STA diameter.

Results : Initial STA flow ranged from 15 mL/min to 85 mL/min, and the flow did not change significantly during occlusion as compared with pre-occlusion flow. The occlusion time was extended by 30 minutes in all cases, but this did not contribute to any significant flow change.

Conclusion : The amount of bypass flow in the STA seems to be influenced not by donor vessel status but by recipient vessel demand. Ligation of the unused STA branch after completion of anastomosis does not contribute to improvement in bypass flow immediately after surgery, and furthermore, carries some risk of skin necrosis. It is better to leave the unused branch of the STA intact for use in secondary operation and to prevent donor vessel occlusion.

KEY WORDS : STA-MCA anastomosis · Flow change · Donor vessel.

INTRODUCTION

The superficial temporal artery to middle cerebral artery (STA-MCA) bypass is a technique that provides a conduit for blood flow directly from the external carotid system to the intracranial vessels. STA-MCA bypass has been used by neurosurgeons for more than 30 years in the management of neurovascular disorders such as atherosclerotic steno-occlusive disease, Moyamoya disease, and complex intracranial aneurysms^{1,5,6,10,12,14,15}. Many authors have described the safety and efficacy of STA-MCA bypass for the treatment of ischemic cerebrovascular disease^{10,14}. Some neurosurgeons intentionally ligate the unused branch of the superficial temporal artery after completion of the anastomosis for the purpose of

improving bypass flow to the cerebrum^{4,7,15}. The purpose of this study was to investigate changes in bypass flow when the unused branch of the STA was temporarily occluded during surgery and to determine whether there is any advantage to ligating the unused branch.

MATERIALS AND METHODS

Twelve consecutive STA-MCA bypasses were performed by a single neurovascular surgeon for the treatment of symptomatic steno-occlusive cerebrovascular disease due to hemodynamic insufficiency. All patients or legal guardians provided informed consent and the study protocol was approved by the institutional review boards at our institution.

Table 1 represents demographic information for the patients. Preoperative work-ups included conventional catheter angiography and magnetic resonance imaging (MRI) or computed tomography (CT) angiography. Hemodynamic insufficiency was assessed using functional blood flow study with hexamethyl-propyleneamine oxime single photon emission computed tomography (HSPAO-SPECT) before

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Table 1. Summary of treatment and clinical data for 12 patients

Case	Age/Sex	Diagnosis	Operation procedure	STA patency*	STA patency [†]	2-STA diameter change
1	50/M	Occlusion, ICA	STA-MCA bypass	Yes	Yes	Increased
2	43/F	MMD	STA-MCA bypass with EDAS	Yes	Yes	Increased
3	49/M	Occlusion, ICA	STA-MCA bypass	Yes	Yes	No change
4	67/M	Occlusion, MCA	STA-MCA bypass	Yes	Yes	Increased
5	51/M	Occlusion, ICA	STA-MCA bypass	Yes	Yes	No change
6	51/F	MMD	STA-MCA bypass with EDAS	Yes	Yes	Increased
7	68/F	Occlusion, MCA	STA-MCA bypass	Yes	Yes	No change
8	51/F	MMD	STA-MCA bypass with EDAS	Yes	Yes	Increased
9	15/M	MMD	STA-MCA bypass with EDAS	Yes	Yes	Increased
10	48/F	Occlusion, MCA	STA-MCA bypass	Yes	Yes	Increased
11	53/F	Occlusion, MCA	STA-MCA bypass	Yes	Yes	Increased
12	48/F	MMD	STA-MCA bypass with EDAS	Yes	Yes	Increased

*Immediately, [†]Follow up DSA. EDAS : encephaloduroarteriosynangiosis, ICA : internal carotid artery, MCA : middle cerebral artery, MMD : moyamoya disease, STA : superficial temporal artery

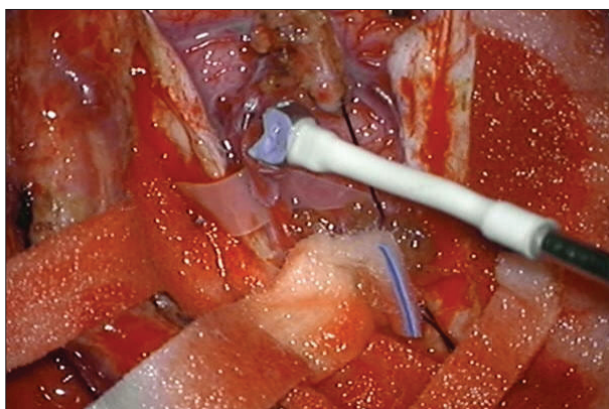


Fig. 1. Intraoperative photograph. After completion of anastomosis, bypass blood flow is being measured using a quantitative microvascular ultrasonic flow probe.

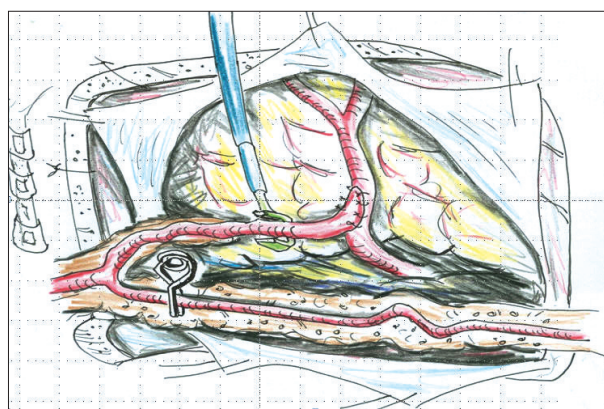


Fig. 2. Bypass blood flow is measured and recorded after temporary occlusion.

and after the administration of acetazolamide.

All patients were placed under general anesthesia with a combination of isoflurane and intravenous agents. Hyperventilation was not used; therefore, arterial PCO₂ was maintained between 35 and 40 mmHg. A direct anastomosis between the STA and a distal branch of the MCA was established using an end-to-side technique that is described in detail elsewhere^{4,15}.

One branch of the STA was used as a donor. The other branch of the STA was either used as the pedicle for encephaloduroarteriosynangiosis (EDAS) or left intact to supply the scalp. Intraoperative patency of the anastomosis was confirmed by visualized pulsation of the vessel and by micro-Doppler measurement (Nicolet Biomedical, Madison, WI, USA). Bypass blood flow was measured by a quantitative microvascular ultrasonic flowmeter (Charbel Micro-Flow-probe; Transonics Systems, Inc., Ithaca, NY, USA) before temporary occlusion of the unused branch of the STA. The probe was applied to the distal part of the STA just before anastomosis and the blood flow was measured for at least 5 minutes

for each patient (Fig. 1). We began to assess occlusion when the flow rate stabilized, and bypass blood flow was measured and recorded at 1, 2, 3, 4, 5, 15, and 30 minutes after temporary occlusion (Fig. 2). All patients underwent CT angiography within 1 day post-operation and then underwent conventional catheter angiography within 6 months to assess the patency and diameter of the STA.

RESULTS

Five men and seven women were enrolled in this study. The average age of the subjects was 49 years, ranging from 15 to 68 years. In 7 cases of atherosclerotic steno-occlusive disease, STA-MCA bypasses were performed using one vessel. In 5 cases of Moyamoya disease, STA-MCA bypasses with EDAS were performed.

Fig. 3 represents STA flow rates before and after the occlusion test as a function of time. STA flow varied from person to person, ranging from 15 mL/min to 85 mL/min. In the 5 cases of Moyamoya disease, STA flow tended to be at the

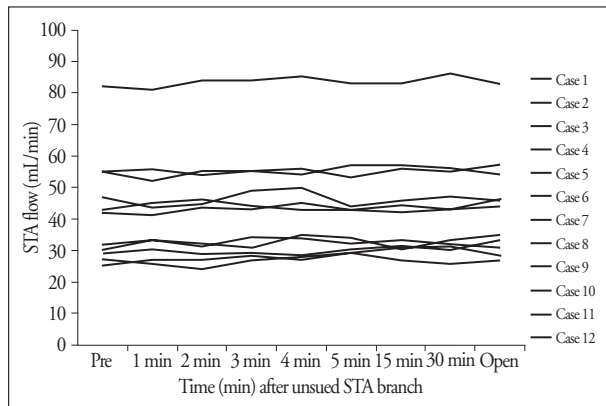


Fig. 3. Bypass blood flow before and after temporary occlusion of unused branch of STA measured by quantitative microvascular ultrasonic flow probe. STA : superficial temporal artery.

lower end of the range, with a maximum flow rate of 35 mL/min.

We observed little flow change during temporary occlusion compared with pre-occlusion flow in all patients. The occlusion time was extended to 30 minutes in all cases and even with this time increase, there was little flow change. These results suggest that in-flow does not change significantly during temporary occlusion of the unused branch of the STA after anastomosis.

There were no cases of mortality and surgery-related morbidity in our 12 patients. At 6 month follow-up visits, all 12 patients had improved or remained stable, compared to their preoperative conditions. Bypass patency was evaluated with CT angiography immediately after surgery, and demonstrated good visualization of the STA in all patients. Conventional catheter angiography performed 6 months postoperatively revealed excellent collateral flow through the STA in all patients. With the exception of 3 cases, STA diameters were increased at 6 months compared with CT angiography results obtained immediately following the operation.

DISCUSSION

Cerebral revascularization may be required before therapeutic occlusion of the internal carotid artery (ICA) for selected aneurysms or cranial base lesions. The indications for extracranial-intracranial (EC-IC) bypass fall into two major categories : 1) flow replacement in the treatment of complex aneurysms or tumors that require vessel sacrifice, and 2) flow augmentation for the treatment of cerebral ischemia associated with misery perfusion^{5,6,10,12,14,15}. A previous randomized, multi-center trial failed to demonstrate that EC-IC bypass could prevent further cerebral ischemia in patients with atherosclerotic ICA or MCA disease, and after publication of that study, enthusiasm for cerebral revascularization

waned rapidly⁵. However, interest in revascularization had resurged, based on a greater understanding of the importance of assessing cerebral hemodynamic factors. Carefully selected patients with compromised cerebral hemodynamic reserves may have benefit from the procedure. Nussbaum and Erickson¹⁰ used xenon-enhanced CT imaging to evaluate patients failing maximal medical therapy and discovered relative hypoperfusion of the involved hemisphere with poor cerebrovascular reserve. Postoperative reevaluation of patients enrolled in that study revealed significant improvements in hemispheric cerebral blood flow and reserve capacity. In another study, Nussbaum et al.¹¹ carefully selected a group of relatively young patients with severely limited collateral circulation, and found that bypasses were successful in arresting the progression of stroke, and in some cases, resulted in rapid neurological improvement.

Several strategies for increasing collateral flow to the brain have been described. In patients with Moyamoya disease, STA-MCA anastomosis with encephalo-duro-myo-synangiosis is useful for providing increased blood flow to prevent additional ischemia in the area of the anterior cerebral artery⁶. Short vein grafts from the proximal STA to the MCA may be useful as a primary means of cerebral revascularization or as an alternative approach when a scalp artery cannot be used because of its small size, severity of arteriosclerotic changes, or damage during dissection⁸. Simultaneous anastomoses of both branches of the STA to the intracranial vessels or additional anastomoses using the remnant distal part of the STA are alternative methods for improving in-flow.

In the present study, direct intraoperative flow measurements were performed using a microvascular ultrasonic flow probe. Methods for qualitative and quantitative measurement of blood flow have evolved over the years. The use of a flow-assisted surgical technique using intraoperative flow measurements can be helpful for predicting graft patency and efficacy after flow augmentation. Such devices consist of an electronic flow detection unit and a flow-sensing perivascular probe. The flow probe uses the principle of ultrasonic transit time to detect flow in vessels independent of the flow velocity profile, turbulence, or hematocrit^{2,3,9}. The accuracy of measurements with the ultrasonic flow probe has been well established through *in vitro* and *in vivo* studies⁹. Intraoperative flow measurements using the ultrasonic flow probe are highly sensitive for detecting vessel compromises².

In STA-MCA bypass procedures, the cut flow index provides a sensitive predictor of postoperative bypass patency. Cut flow refers to the maximum potential flow capacity of an *in situ* donor vessel, such as the STA. If the resistance in the cortical recipient bed is sufficiently low, as would be expected in the case of symptomatic cerebrovascular occlusive disease

with impaired reserve, the bypass flow would be expected to approximate the cut flow. This can be quantified by calculating the cut flow index (CFI) : $CFI = \text{bypass flow (mL/min)} / \text{cut flow (mL/min)}^2$. The amount of in-flow to the intracranial vessel through the bypass is mainly determined by the status of the cerebral vessel, which is correlated with the cut flow index, not the STA size²⁾.

Some authors recommend ligating the unused branch of the STA to increase blood flow through the bypass^{4,7,15)}. However, in our study, there were no significant changes of in-flow during temporary occlusion of the unused branch of the STA after anastomosis. Based on these results, ligation of this unused branch would not be expected to increase flow in the bypass after anastomosis. On the contrary, ligation may have several disadvantages. In cases of early occlusion of the STA-MCA bypass after surgery, ligation of the unused branch deprives the system of the chance of rescue by recanalization. Scharf et al.¹³⁾ reported that spontaneous recanalization of early occluded STA-MCA bypasses occurred in a high percentage of cases. In addition, in cases where revision is required, the unused branch can be used as a new donor vessel, which would be impossible if the vessel is ligated during the first procedure. Also, there is risk of skin necrosis with ligation.

However, there can be controversies whether temporary occlusion of the unused branch for 30 minutes will yield the same results as permanent occlusion of the vessel. In the present study, DSA after 6 months of operation revealed increase in diameter of the STA in nine of twelve patients. All of them had a characteristics of decreased reserve capacity more than twenty percents (data were not shown in this paper). It means that long term STA flow changes might be influenced by a recipient demand. Further study is needed to ascertain whether the STA flow would vary not by the permanent ligation of the unused branch but the patient's hemodynamic status.

CONCLUSION

Temporary occlusion of the unused STA branch in STA-MCA anastomosis did not lead to improve bypass flow for

30 minutes. Also, there is a risk of skin necrosis with ligation of unused branch. We suggest that surgeons should consider to preserve the unused branch of the STA for future revision surgery or donor patency.

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