Radial Artery Grafts as Rescue Strategy for Patients with Moyamoya Disease for Whom Conventional Revascularization Failed

Satoshi Hori, Güliz Acker, Peter Vajkoczy

■ BACKGROUND: **Failure of direct revascularization with superficial temporal artery (STA)-middle cerebral artery (MCA) bypass for Moyamoya disease (MMD) is comparatively rare. However, for those cases where a bypass fails to prevent further ischemic attacks, safe and efficient rescue strategies are needed. We present our experience with radial artery grafts for secondary revascularization of MMD.**

■ METHODS: **Between April 2007 and April 2014, we have performed STA-MCA bypass in 182 patients diagnosed with Moyamoya vasculopathy. Four patients with typical MMD who had an unsuccessful STA-MCA bypass required additional revascularization because they remained symptomatic. Digital subtraction angiography revealed delayed STA graft failure in these patients, who continued to have transient ischemic attacks after the initial surgery. Cerebral blood flow studies confirmed persistent impairment of cerebrovascular reserve capacity. As an escape strategy, we performed radial artery graft bypass surgery from the external carotid artery to the M2 or M3 portion of the MCA.**

■ RESULTS: **The median duration between the 2 surgeries was 10 months. The mean follow-up period after rescue revascularization was 8.5 ± 3.3 months. Revascularization with the radial artery graft was successful in all cases without perioperative complications. Postoperatively, none of the patients experienced further cerebrovascular events. After 3 months, digital subtraction angiography revealed patent radial artery grafts and adequate revascularization in 3 patients; 1 patient presented with bypass graft failure but had developed transdural collateral vessels contributing to the filling of the cerebral vasculature.**

■ CONCLUSIONS: **Rescue bypass with a radial artery graft provides a useful function. Although delayed graft failure may occur, this procedure is successful if the patients remain symptom free with the development of collateral flow.**

INTRODUCTION

Surgical revascularization for Moyamoya disease (MMD), including direct bypass, indirect bypass, and combined revascularization strategies, have been shown to improve cerebral hemodynamics and prevent further ischemic and hemorrhagic stroke.[1–5] Direct bypass surgery, i.e., primarily superficial temporal artery (STA)-middle cerebral artery (MCA) bypass, can resolve ischemic attacks immediately after surgery.

Previous reports demonstrated that the STA-MCA bypass procedure is characterized by a high early patency rate (90%–96%).[6–13] In contrast, late graft failure may occur in up to 10%.[14] In most cases, late occlusion of the bypass remains asymptomatic and will not result in re-occurrence of ischemic

Key words
- Chronic ischemia
- High-flow bypass surgery
- Hyperperfusion syndrome
- Moyamoya vasculopathy
- STA-MCA bypass

Abbreviations and Acronyms
CBF: Cerebral blood flow
CVRC: Cerebrovascular reserve capacity
DSA: Digital subtraction angiography
ECA: External carotid artery
MCA: Middle cerebral artery
MMD: Moyamoya disease
PET: Positron emission tomography
SPECT: Single photon emission tomography
STA: Superficial temporal artery
TIA: Transient ischemic attack

Department of Neurosurgery, Universitätsmedizin Charite, Berlin, Germany

To whom correspondence should be addressed: Peter Vajkoczy, M.D. [E-mail: peter.vajkoczy@charite.de]

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or hemorrhagic symptoms because either accompanying indirect revascularization techniques have taken over or endogenous collaterals have been established.[15] However, rarely, late STA-MCA graft failure may result in persistent or new transient ischemic attacks (TIAs) and new ischemic stroke.[16] For those patients, rescue revascularization strategies are needed and, currently, no consensus exists on how these patients should be handled surgically.[17,18] Currently, most surgeons would choose indirect revascularization strategies when alternative low-caliber grafts are lacking.[19–21]

Large-caliber graft bypass surgery (using radial artery or saphenous vein grafts) have undisputed indication in the setting of planned vessel sacrifice for complex aneurysms and skull base tumors.[22–24] However, large-caliber graft bypass surgery for patients with MMD is controversial.[17,18] This is due to fear of procedure-related complications, the high fragility of cerebral MMD vessels, and the high risk of hyperperfusion syndrome.

Here, we report our experience with 4 patients who were refractory to conventional revascularization strategies, including STA-MCA bypass, for whom we elected to perform secondary, rescue revascularization using radial artery grafts. We show that large-caliber graft revascularization in MMD patients is technically feasible and has proved to be safe and effective in a limited case series.

METHODS

Patient Population

Between April 2007 and April 2014, we have performed revascularization procedures at our institution on 182 patients with Moyamoya vasculopathy (including MMD and Moyamoya syndrome). MMD was defined according to the guidelines of the Research Committee on Moyamoya Disease of the Ministry of Health and Welfare, Japan.[25] All patients received a diagnostic workup consisting of a neurologic examination, digital subtraction angiography (DSA), magnetic resonance imaging, and 122 patients had functional cerebral blood flow (CBF) studies with either single photon emission tomography (SPECT) or positron emission tomography (PET) with $H_2{}^{15}O$ before and after forced vessel dilatation by acetazolamide (Diamox) before surgery. The criteria for revascularization were symptomatic MMD defined as TIAs or ischemic stroke (including hemorrhagic stroke in patients with MMD), and proof of a severely restricted or abrogated reserve capacity detected by either SPECT or PET. Surgical treatment was performed using a standard STA-MCA bypass plus indirect revascularization with either encephalomyosynangiosis or encephalodurosynangiosis.[26] In all patients, the clinical findings were evaluated and DSA and/or computed tomographic angiography was performed after surgery for evaluation of bypass patency. Failure of revascularization was diagnosed if the patient was symptomatic and had new ischemic border-zone lesions on magnetic resonance imaging, DSA demonstrated bypass graft failure, and the CBF study showed persisting impaired cerebrovascular reserve capacity (CVRC). Four patients with MMD matched these criteria and underwent rescue revascularization. The age of these patients ranged from 15 to 57 years (mean ± SE, 34 ± 7.6 years). The data were analyzed retrospectively.

Surgical Procedures

All patients were revascularized using radial artery grafts. First, the radial artery was harvested in a typical manner. The graft vessel was dilated with controlled hydrostatic pressure and checked for leakage. Next, the patients underwent a frontotemporal craniotomy, which expanded the initial craniotomy and incision of the dura. Because of the previous indirect surgery, it was necessary to separate the donor tissue from the underlying brain with careful dissection. The Sylvian fissure was gently opened to approach the M2 portion of the MCA. After we carefully observed the size and strength of the vessel wall of the M3 portion and considered that it was suitable for use as a recipient artery, we performed the anastomosis to the M3 portion. If the M3 portion was not suitable, we selected the M2 portion for a recipient artery.

The first anastomosis was performed between the proximal end of the graft vessel and the external carotid artery (ECA), using an end-to-side technique, just distal to the bifurcation of the common carotid artery (**Figure 1A**). The mean occlusion time necessary for this anastomosis was 18 minutes. The graft vessel passed upward beneath the skin. After the proximal anastomosis was achieved, anastomosis of the distal end of the graft vessel and the M2 or M3 portion of the MCA was performed using the end-to-side technique (**Figure 1B, C**). The mean occlusion time necessary for this anastomosis was 23 minutes. The patency of the graft vessel was confirmed by intraoperative indocyanine green angiography (**Figure 1D**) and quantitative Doppler flow measurements.

Perioperative Management

The patients were maintained under normotensive conditions (120–140 mm Hg, systolic blood pressure) immediately after anastomosis. The patients were observed carefully in the intensive care unit after surgery for symptoms raising suspicion of hyperperfusion, such as headache, seizure, and focal neurologic deficit. A postoperative computed tomography scan was routinely performed 1 day after surgery.

Follow-Up Data

The patients were followed up routinely 3 months and 12 months after surgery. Postoperative DSA and/or computed tomographic angiography was performed for evaluation of bypass graft patency within 1 week after surgery. A follow-up DSA was obtained at 3 months after surgery.

RESULTS

Initial Surgery

All patients with MMD underwent STA-MCA bypass, and 3 patients also underwent indirect bypass surgery, which included encephalomyosynangiosis in 2 patients and encephalodurosynangiosis in 1 patient (**Table 1**).

Indications for Additional Surgery

All 4 patients were initially free of symptoms but relapsed 5 months to 13 years (median, 10 months) after the initial surgery and became symptomatic again in the ipsilateral hemisphere with TIAs and strokes. All patients showed failed initial revascularization due to delayed occlusion of the STA-MCA bypass. Hexamethylpropylene amine oxime-SPECT with the administration of