Indirect Bypass Surgery May Be More Beneficial for Symptomatic Patients with Moyamoya Disease at Early Suzuki Stage

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■ OBJECTIVE: **Moyamoya disease is a progressive stenosis or occlusion of the internal carotid artery. Revascularization surgery is considered the standard treatment. We conducted a retrospective study in hopes of finding indications for electing different surgical methods.**

■ METHODS: **A total of 55 hemispheres in 49 patients who received revascularization surgery between January 2013 and December 2015 were included. Medical data such as age and sex were extracted and risk factor analysis for vascular anastomosis patency was conducted with multivariable logistic regression.**

■ RESULTS: **In this study, direct or combined bypass surgery had a higher incidence of perioperative neurologic defects than did indirect surgery (30.3% vs. 4.5%; $P = 0.046$). The rates of postsurgery stroke (6.2% vs. 18.2%) and modified Rankin Scale improvement (39.4% vs. 18.2%) were better in the direct or combined bypass surgery group, but no significant difference was found. Moreover, longer operative time (209 $\pm$ 29.4 minutes vs. 101 $\pm$ 16.5 minutes; $P < 0.01$) and longer hospital stay (9.0 $\pm$ 3.11 days vs. 5.3 $\pm$ 2.03 days; $P < 0.01$) made direct or combined bypass surgery less advantageous. Multivariable binary logistic regression showed that the late Suzuki stage is a more favorable factor than the early Suzuki stage (odd ratio, 7.78; confidence interval, 1.059–57.155; $P = 0.044$).**

■ CONCLUSIONS: **Because vascular anastomosis patency in symptomatic patients with moyamoya disease at early Suzuki stage is relatively lower, indirect bypass surgery may be more beneficial for these patients in view of shorter operative time and hospital stay.**

INTRODUCTION

Moyamoya disease (MMD) is a progressive stenosis or occlusion of the internal carotid artery with an unknown cause.[1] The most common clinical manifestation of MMD is ischemic or hemorrhagic stroke.[2] Without intervention, MMD often leads to serious neurologic defects or even death.[2-5] Revascularization surgery is considered the standard treatment for symptomatic MMD because it improves cerebral blood flow through new collateral vessels.[6-10]

There are at least 7 different surgical methods for treating MMD, and they can be grouped as direct, indirect, or combined bypass surgery approaches.[6,11,12] Superficial temporal artery (STA)—middle cerebral artery anastomosis, encephalomyosynangiosis (EMS), and encephaloduroarteriosynangiosis (EDAS) are relatively common surgical procedures. Direct or combined bypass surgery is superior to indirect bypass surgery for stroke prevention,[6,9,10,13] but because it is easier to use and there are fewer perioperative complications, indirect bypass surgery is often performed.[14,15]

Vascular anastomosis patency (VAP) is the key factor for success in direct bypass surgery. However, the risk factors of VAP are unclear. Here, we review our previous cases to evaluate possible

Key words
- Bypass surgery
- Cerebrovascular disease
- Moyamoya disease
- Suzuki stage
- Vascular anastomosis patency

Abbreviations and Acronyms
CT: Computed tomography
EDAS: Encephaloduroarteriosynangiosis
EMS: Encephalomyosynangiosis
MMD: Moyamoya disease
mRS: Modified Rankin Scale
STA: Superficial temporal artery
VAP: Vascular anastomosis patency

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risk factors of VAP and provide some experience for choosing the appropriate treatment approach.

METHODS

This study was approved by the ethics committee of Zhejiang University School of Medicine Second Affiliated Hospital.

Patients

We searched our electronic medical records to identify eligible patients who were admitted to our hospital between January 2013 and December 2015. All patients who met the following criteria were included in this study: 1) diagnosis of definite MMD or moyamoya syndrome via digital subtraction angiography, magnetic resonance angiography, or computed tomography (CT) angiography; 2) presentation with symptoms related to MMD such as stroke; 3) undergoing revascularization surgery for the treatment of MMD; and 4) available follow-up information, including radiologic data from 3 to 6 months after surgery. We extracted medical data, including age, sex, body mass index, smoking, alcohol use, diabetes, hypertension, antiplatelet drug use, MMD type (hemorrhagic or ischemic), Suzuki stage, disease duration before surgery, perioperative neurologic defects, operative time, and length of hospital stay. The patency of the bypass pedicle was assessed using digital subtraction angiography, CT angiography, or magnetic resonance angiography between 3 and 6 months after surgery. The initial Suzuki stage of the patients was divided into 2 groups as follows: Suzuki stages 1–3 were defined as early Suzuki stage and Suzuki stages 4–6 were defined as late Suzuki stage. Patients' cerebral blood flows were measured by CT perfusion and the cerebral blood flows were judged by experienced radiologists according to these CT perfusion images. Postoperative stroke was observed and modified Rankin Scale (mRS) scores were collected both before and after surgery.

Surgical Procedures

We tended to perform the direct bypass, but if initial assessments showed that donor and recipient were mismatched, the indirect bypass surgery was performed. In this situation, we sometimes assessed STA and M4 intraoperatively before the revascularization type was decided. For patients who underwent combined bypass surgery, a frontotemporal craniotomy was used. The STA was used as the donor artery and the cortical branches of the middle cerebral artery (M4) were selected as the recipients. Anastomosis was accomplished with 10-0 prolene suture in all cases using an interrupted suture technique. At the end of the vascular anastomosis, fluorescence angiography was performed to confirm the anastomosis site patency. EDAS or EMS was used as the indirect bypass surgery. In this study, we first chose EDAS as the indirect revascularization procedure, and EMS was also used when EDAS failed because of the improper STA. All vascular anastomosis procedures were performed by the same neurosurgeon.

Perioperative Treatment

Prophylactic control of systolic blood pressure between 120 mm Hg and 140 mm Hg was used to prevent hyperperfusion syndrome or anastomotic occlusion because of low blood pressure.[16] An antiplatelet agent was administered 24 hours after intracranial hemorrhage had been ruled out by CT scan.

Data Analysis

Statistical analysis was conducted using SPSS (version 20.0 [IBM Corp., Armonk, New York, USA]). Continuous variables were expressed as the mean ± standard deviation. The χ^2 or Fisher exact tests were used for univariate analysis of categorical variables. The Student t-test or nonparametric test was used for the univariate analysis of continuous variables. Potentially significant variables picked out from univariate analysis were all included in the binary logistic regression analysis to determine the risk factors for VAP and the odds ratios for each risk factor. Results for which $P < 0.05$ were considered to be significant.

RESULTS

We identified 49 patients who met the criteria for study inclusion. A total of 55 hemispheres received revascularization surgery. Of the 49 patients, 30 patients and 33 hemispheres received direct or combined bypass surgery and 19 patients and 22 hemispheres underwent indirect bypass surgery. Of these 55 hemispheres, 21 belonged to the early Suzuki stage, whereas the others belonged to the late Suzuki stage. A summary of these patients' characteristics are shown in Table 1; none of them except the Suzuki stage was significantly different.

Perioperative neurologic defects occurred in 11 hemispheres. Direct or combined bypass surgery compared with indirect bypass surgery led to a higher incidence of these defects (30.3% vs. 4.5%; $P = 0.046$; Table 2). Among these patients, 2 developed long-term neurologic defects (3.6%, 2/55 hemispheres), no significant difference was found between the direct and indirect bypass for 6 months (6.1% vs. 0%; $P > 0.05$), and they had both received direct or combined bypass surgery. Seven patients had perioperative seizure, but no significant difference was found between the direct and indirect bypass surgery groups (9.1% vs. 18.2%; $P = 0.563$); all cases were resolved by antiepileptic drugs. Both the operative time and length of hospital stay were statistically longer in the direct or combined bypass surgery group (Table 2).

Postoperative stroke occurred in 6 cases, and no significant difference was found between the groups (6.2% vs. 18.2%; $P = 0.331$). The direct or combined surgery group had more cases that showed improvement in mRS score, but no statistical significance was found (39.4% vs. 18.2%; $P = 0.197$) (Table 2).

We found that anastomosis often narrowed and sometimes even occluded during the follow-up period; instead, good new collateral vessels could grow from other origins such as the deep temporal artery, which supplies the temporalis (Figure 1). The VAP 6 months later in the direct or combined surgery group was 63.6%. Further analysis of risk factors of VAP showed that the late Suzuki stage was a more favorable factor than the early Suzuki stage (odds ratio, 7.78; confidence interval, 1.058–57.155; $P = 0.044$) and VAP of early Suzuki stage was obviously lower than that of late Suzuki stage (44.4% [4/9] vs. 70.8% [17/24]) (Table 3). Although the incidence of postoperative stroke in good VAP was lower than that of poor VAP (0 vs. 16.7%), no significance was found. The 6 month mRS improvement of the early Suzuki stage was higher (55.6% vs. 33.3%) and the 6-month mRS improvement in the good