Indirect Revascularization for Non–Moyamoya Disease Anterior Circulation Arterial Steno-occlusion: Clinical Features, Surgical Treatment, and Medium-Term Outcomes in Adults

Huaiyu Tong[1], Yudong Ma[1], Zhiyuan Zhang[1,2], Zhiqi Mao[1], Baojun Yao[3], Aijia Shang[1], Ruozhuo Liu[1], Xinguang Yu[1], Dingbiao Zhou[1]

■ BACKGROUND: **Symptomatic anterior arterial steno-occlusion is often associated with neurofunctional deficits or a high risk of recurrent stroke or both. Although both medical and endovascular treatments are useful and suitable, few studies have investigated the continued use of indirect encephaloduroarteriosynangiosis (EDAS) bypass in patients with non–moyamoya disease ischemia. We retrospectively investigated clinical features, surgical treatments, and medium-term outcomes of indirect revascularization for patients with non–moyamoya disease anterior circulation arterial steno-occlusion in China.**

■ METHODS: **EDAS without burr holes was performed in 51 adult patients with cerebral ischemic events and diagnosed nonmoyamoya anterior circulation arterial steno-occlusion. Preoperative, postoperative, and follow-up neurologic status was evaluated using the National Institutes of Health Stroke Scale; changes on angiography and perfusion-weighted magnetic resonance imaging were evaluated.**

■ RESULTS: **Unilateral EDAS was performed in 48 patients, and bilateral EDAS was performed in 3 patients. Four patients experienced complications before hospital discharge; only 23 patients underwent follow-up angiograms. Of the 51 patients, 44 (86.3%) exhibited improved muscle strength; 21 of 23 patients (91.3%) with follow-up angiography data exhibited evidence of new visible branches from the superficial temporal artery or middle meningeal artery or both. Preoperative and postoperative perfusion-weighted magnetic resonance imaging was performed for 5 patients. Despite clinical improvement in all patients, only 2 exhibited hemodynamic improvement.**

■ CONCLUSIONS: **Indirect revascularization may be safe and effective for improving blood flow to the ischemic region following nonmoyamoya anterior circulation arterial steno-occlusion, especially in patients with residual post-infarction neurologic deficits. Our study demonstrates that improvements in ischemic symptoms after EDAS correspond to neovascularization from the superficial temporal artery or middle meningeal artery in ischemic brain areas.**

INTRODUCTION

Approximately 2 million cases of ischemic stroke occur each year in China. Of these, 70% are caused by anterior circulation arterial stenosis or occlusion. Some medical, endovascular, and surgical treatments are unsuitable for certain patients with particular types of anterior circulation arterial stenosis or occlusion. At the present time, direct bypass procedures, which are complex and difficult, are performed at only a few institutions in China. By contrast, encephaloduroarteriosynangiosis (EDAS), which features an easily mastered procedure, has been

Key words
- Anterior circulation
- Cerebral arterial occlusion
- Cerebral arterial stenosis
- Encephaloduroarteriosynangiosis
- Indirect revascularization

Abbreviations and Acronyms
CT: Computed tomography
DSA: Digital subtraction angiography
EDAS: Encephaloduroarteriosynangiosis
MCA: Middle cerebral artery
MMA: Middle meningeal artery
NIHSS: National Institutes of Health Stroke Scale
PWI: Perfusion-weighted magnetic resonance imaging
STA: Superficial temporal artery
TIA: Transient ischemic attack

From the [1]Department of Neurosurgery, Chinese PLA General Hospital, Beijing; [2]Department of Neurosurgery Liaocheng People's Hospital, 67 Dongchang Road, Liaocheng City, Shandong 252000, China; and [3]Department of Neurosurgery, Chinese 252 Hospital, Hebei, China

To whom correspondence should be addressed: Dingbiao Zhou, M.D. or Xinguang Yu, M.D. [E-mail: xinguang_yu@263.net or zhoudingbiao301@163.com]

Huaiyu Tong, Yudong Ma, and Zhiyuan Zhang are co–first authors.

Citation: World Neurosurg. (2016) 89:293-300.
http://dx.doi.org/10.1016/j.wneu.2016.02.012

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

shown to be beneficial in adult patients with moyamoya disease and ischemic symptoms.[1-7] However, only a few published studies have demonstrated the efficacy of this procedure for patients with non–moyamoya disease steno-occlusive cerebrovascular disease.[8-10] In this retrospective study, we describe our clinical experience and assess the therapeutic effects of EDAS for the treatment of adult patients with non–moyamoya disease anterior circulation arterial steno-occlusion with ischemic symptoms.

MATERIALS AND METHODS

Patient Selection

All research protocols involving human participants were reviewed and approved by the local ethics committee of the Chinese People's Liberation Army Medical Academy. Written informed consent was obtained from all patients. Patients underwent treatment including EDAS if they met all of the following criteria: history of symptomatic cerebrovascular disease; stenosis and occlusion of the internal carotid artery or proximal segment of the middle cerebral artery (MCA) secondary to inflammation, atherosclerosis, or an unknown etiology; severe stenosis considered unsuitable for endovascular treatment; and failed stent procedure with restenosis or occlusion.

Preoperative Evaluation

Epidemiologic risk factors associated with the disease were determined. Neurologists assessed patients' neurologic status using the National Institutes of Health Stroke Scale (NIHSS) (Table 1). Patients underwent both brain magnetic resonance imaging and digital subtraction angiography (DSA) for diagnostic confirmation. In 5 patients, additional perfusion-weighted magnetic resonance imaging (PWI) was performed to evaluate local brain blood flow. Poor collateral circulation was defined according to DSA findings as described previously by Gu et al.[10] All patients received conservative treatment for at least 1 month to ensure a stable condition during the acute phase of ischemic stroke. The primary clinical outcome endpoint was stroke or death at the end of the last follow-up, and the secondary endpoint was persistent or recurrent transient ischemic attack (TIA) at the end of the last follow-up.

Surgical Treatment

Perioperative care and surgical method exactly as described previously for patients with moyamoya disease were used in this study.[1,7,11] For patients with moyamoya disease treated with EDAS, consensus indicates that protection of the middle meningeal artery (MMA) is very important, and close attention is warranted while the dura mater is open to ensure retention of the MMA branches to the extent possible.[8,10] As mentioned earlier, we undertook similar considerations in this study.

Briefly, blood pressure was strictly controlled in the range of 120–140 mm Hg to avoid hypotension for the duration of the surgical procedure. Hyperventilation was avoided to prevent vasoconstriction caused by hypocapnia. All patients received aspirin (100 mg daily) during the perioperative period.

Postoperative Assessment and Clinical Follow-Up

Long-term outcomes were evaluated through clinical visits and interviews via telephone or mail. Postoperative stroke was defined as a new neurologic function deficit with a duration of at least 24 hours that was associated with a new infarct or hemorrhage on magnetic resonance imaging or computed tomography (CT) during the first 30 days after the EDAS procedure, regardless of the presence of a new neurologic deficit. At 6 months after EDAS, establishment of collateral circulation and collateral circulation function were assessed using DSA if possible. In addition, we comparatively analyzed the hemodynamic status of 5 patients using preoperative and postoperative PWI. Development of collateral circulation after EDAS was classified using the system described by Matsushima et al.,[11] with grades A, B, and C. NIHSS scores were used to evaluate improvements in neurologic function after EDAS treatment.

Statistical Analysis

Preoperative and postoperative NIHSS scores, preoperative and follow-up NIHSS scores, and postoperative and follow-up NIHSS scores were compared to determine the degrees of improvement in neurologic function. Probability (P) values of $\leq$ 0.05 were considered to indicate statistical significance.

RESULTS

Demographics and Clinical Presentation

Between March 2006 and May 2013, 51 adult patients without moyamoya disease were treated by EDAS at the Department of Neurosurgery, PLA General Hospital, Beijing. Mean patient age

Table 1. National Institutes of Health Stroke Scale Scores at Admission, Discharge, and Follow-Up

Neurologic Status (NIHSS Score)	Admission	Discharge	Follow-Up
0	10	9	13
1–3	25	28	32
4–10	14	12	5
11–15	1	1	0
≥16	1	1	1
Mean NIHSS scores	3.059	2.882	1.824
Paired *t* tests	Admission to discharge: $P < 0.001$	Discharge to follow-up: $P \leq 0.001$	Follow-up to admission: $P \leq 0.001$

NIHSS, National Institutes of Health Stroke Scale.