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Common features in patients with intracerebral hemorrhage following superficial temporal artery-middle cerebral artery bypass in steno-occlusive cerebrovascular disease☆

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Abstract

Five patients treated for intracranial cerebral hemorrhage after superficial temporal artery-middle cerebral artery bypass in Xuwu Hospital, Capital Medical University, Beijing, China, from 2005–2011 were included in this study. Prior to superficial temporal artery-middle cerebral artery bypass, all patients showed diminished cerebrovascular reactivity and an ipsilateral ischemic lesion. Intracranial cerebral hemorrhage developed within 1–4 days following superficial temporal artery-middle cerebral artery bypass. Transcranial Doppler showed increased middle cerebral artery velocity of 50–100% in the operated hemisphere. These findings suggested that focal hyperperfusion, an ipsilateral ischemic lesion and diminished cerebrovascular reactivity are the important characteristics of intracerebral hemorrhage following superficial temporal artery-middle cerebral artery bypass in patients with steno-occlusive cerebrovascular disease.

Key Words

cerebral hemorrhage; STA-MCA, superficial temporal artery-middle cerebral artery bypass; stenosis; occlusion; cerebrovascular disorders; hyperperfusion; ischemic lesion; cerebrovascular reactivity; brain injury; regeneration; neural regeneration

Research Highlights

(1) Patients with intracranial cerebral hemorrhage following superficial temporal artery-middle cerebral artery (STA-MCA) bypass in steno-occlusive cerebrovascular disease were retrospectively reviewed. (2) Focal hyperperfusion, an ipsilateral ischemic lesion and diminished cerebrovascular reactivity were the common characteristics in patients with intracranial cerebral hemorrhage following STA-MCA bypass. (3) Blood pressure control and free radical scavenger use could prevent postoperative intracranial cerebral hemorrhage after STA-MCA bypass.

Abbreviations

STA-MCA: superficial temporal artery-middle cerebral artery; ICH: intracerebral hemorrhage

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INTRODUCTION

Superficial temporal artery-middle cerebral artery (STA-MCA) bypass was first performed by Yasargil *et al* [1] in a patient with occlusive middle cerebral artery in 1967. Subsequently, thousands of cases have received STA-MCA bypass, and many patients have benefitted from the prevention of stroke secondary to steno-occlusive cerebrovascular disease[2-3]. However, postoperative intracerebral hemorrhage (ICH) may lead to significant morbidity and mortality after STA-MCA bypass, as a rare complication. Okada *et al* [4] reported two patients with perioperative ICH among 30 patients who received STA-MCA

anastomosis for moyamoya disease. Fujimura and Kuriyama *et al* [5-6] analyzed four patients with severe headache and subarachnoid hemorrhage or ICH after STA-MCA bypass. Fujimura *et al* [7] attributed the delayed ICH after STA-MCA bypass to cerebral hyperperfusion associated with increased vascular permeability at the site of the anastomosis. We reviewed five patients with postoperative ICH after STA-MCA anastomosis in steno-occlusive cerebrovascular disease to clarify the common characteristics, and to identify the patients at risk for ICH after STA-MCA bypass to design preventative strategies.

RESULTS

The clinical data from five patients with postoperative ICH after STA-MCA bypass are shown in Table 1.

Prior to STA-MCA bypass, all patients presented with diminished cerebrovascular reactivity and an ischemic lesion in the operated hemisphere. Three patients received two-branch bypass of the superficial temporal artery, and two patients received one-branch bypass. Life signs in all patients remained stable following STA-MCA bypass.

After STA-MCA bypass, cases 1–3 required blood pressure control with intravenous urapidil. Blood pressure in cases 4, 5 was stable [systolic pressure/ diastolic pressure less than 150/95 mm Hg (1 mm Hg = 0.133 kPa)]. Cases 1 (Figure 1) and 2 (Figure 2) had only temporary high blood pressure (≥ 200 mm Hg systolic pressure, or ≥ 110 mm Hg diastolic pressure) because medication was not used continuously.

Transcranial Doppler showed increased middle cerebral artery velocity of 50–100% in the operated hemisphere in three patients. CT scan on day 1 post-operation in all patients showed no diffuse or patchy white matter edema or mass in the region ipsilateral to the STA-MCA.

Table 1 Baseline data of cases

Case	Age (year)	Sex	Initial symptoms	Diagnosis	Concomitant diseases	Preoperative ischemic lesion on MRI
1	48	Male	Right extremities weakness and aphasia attack	Left MCA severe stenosis	Hypertension, diabetes	Left temporoparietal lobe
2	47	Male	Aphasia attack	Left ICA occlusion	Hypertension	Left temporal lobe and basal ganglion
3	53	Male	Dizziness and aphasia attack	Left MCA occlusion	Hypertension	Left temporal lobe
4	41	Male	Right extremities numbness attack	Moyamoya disease	No	Left temporal lobe
5	42	Male	Dizziness and blurred vision	Left ICA occlusion	No	Left occipital lobe

Case	Donor branches of STA	Days from operation to hemorrhage	Symptoms related to ICH	Postoperative MCA velocity	Hemorrhagic site on CT scan	Therapy for ICH	Discharging GOS
1	2	3	Aphasia	Decreased, inverse	Left temporal lobe	Medication	4
2	1	1	Aphasia	Increased by 67%	Left frontal and temporal lobe	Operation	5
3	1	4	Aphasia	Increased by 35%	Left temporal lobe	Medication	4
4	2	3	Right extremities weakness	Increased by 72%	Left temporal lobe	Operation	5
5	2	2	Dizziness and drowsy	Increased by 84%	Left parietooccipital lobe	Operation	3

MCA: Middle cerebral artery; ICA: internal carotid artery; ICH: intracerebral hemorrhage; STA: superficial temporal artery; GOS: Glasgow Outcome Scale.

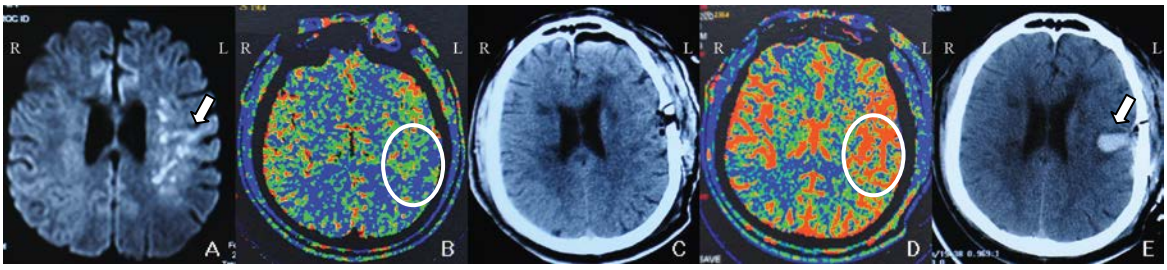

Figure 1 MRI and CT images of a 48-year-old male patient with intracerebral hemorrhage following superficial temporal artery-middle cerebral artery (STA-MCA) bypass.

Preoperative diffusion-weighted MRI demonstrated a left frontotemporal ischemic lesion (white arrow) (A) and perfusion CT revealed lower cerebral blood flow in circled area compared to the right side (B). After STA-MCA anastomosis, CT scan showed no diffuse white matter edema on day 1 post-operation (C). Postoperative perfusion CT showed improved cerebral blood flow in the region ipsilateral to the STA-MCA bypass, and cerebral blood flow was greater in the circled area compared with the contralateral side (D). Temporal hemorrhage (white arrow) was observed in CT images on day 3 (E). L: Left; R: right.

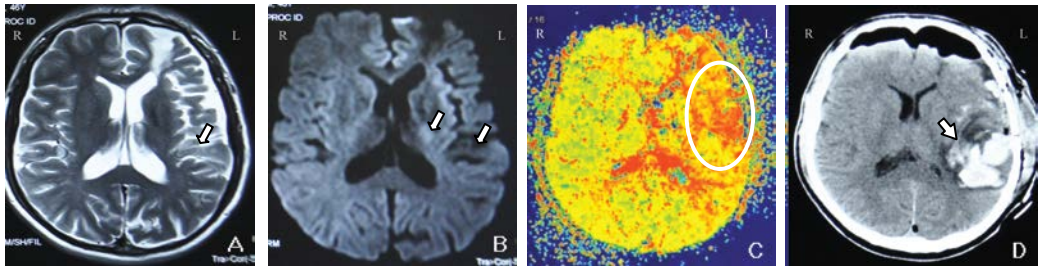

Figure 2 MRI and CT images of a 47-year-old male patient with intracerebral hemorrhage following superficial temporal artery-middle cerebral artery (STA-MCA) bypass.

An ischemic lesion appeared in the left frontotemporal lobe (white arrow) on preoperative MRI (A, B). The time to peak cerebral blood flow velocity in the frontotemporal lobe was delayed compared with the contralateral side (C). CT scan demonstrated left frontotemporal hemorrhage (white arrow) on the first day after STA-MCA bypass (D). L: Left; R: right.

ICH developed within 1–4 days following STA-MCA bypass. The main presentations related to postoperative ICH were focal neurological deficits such as expressive aphasia and extremity weakness (Table 1).

After ICH was identified, the patients were given the free radical scavenger, edaravone and blood pressure was controlled with medication. Three patients received emergent surgical procedures to remove the ICH, and another two patients received medical therapy. During the surgical procedure, no bleeding from the anastomosis site was found. All patients recovered within 1 month after ICH occurrence. The mean Glasgow Outcome Scale score was 4.2 ± 0.7 (range, 3–5) at discharge.

DISCUSSION

Postoperative ICH is a rare complication of STA-MCA bypass. Przybylski *et al* [8] reported one ICH patient in 12 extracranial-to-intracranial bypass patients with symptomatic carotid artery occlusion. Okada *et al* [4] reported that among 30 successive STA-MCA anastomosis patients, two patients exhibited postoperative ICH. Fujimura *et al* [5-7, 9-10] reported one patient with postoperative ICH and two patients with subarachnoid hemorrhage in 58 patients. Lee *et al* [11] also analyzed various hemodynamic factors in 292 patients with moyamoya disease and found that seven patients (2.4%) developed postoperative ICH. In this study, we reported five cases (5/124, 4.0%) with steno-occlusive cerebral vascular disease. In these patients, ICH occurred 1–4 days after STA-MCA anastomosis. Hypertension or hyperperfusion is considered the cause of the hemorrhage. Okada *et al* [4] reported two patients with postoperative ICH who showed hypertension (> 200 mm Hg systolic pressure). Lee *et al* [11] analyzed middle cerebral artery flow velocity using a perivascular ultrasonic flow probe in moyamoya disease patients. The authors found that postoperative hemorrhage was greatly associated with middle cerebral artery flow velocity post-anastomosis (32.1 ± 10.2 mL/min), while the mean middle cerebral artery flow velocity during the anastomosis was 22.2 ± 0.8 mL/min. Fujimura *et al* [7] found a significant increase in cerebral blood flow in the operated hemisphere and suggested that the delayed ICH was due to cerebral hyperperfusion after STA-MCA anastomosis. We also found increasing postoperative cerebral blood flow on the operated side in our patients. Also, all patients who received STA-MCA bypass showed diminished cerebrovascular reactivity. Previous studies demonstrated that patients who showed reduced cerebral blood flow and diminished cerebrovascular reactivity were most likely to develop postoperative hyperperfusion[12]. Therefore, cerebral hyperperfusion can lead to ICH after STA-MCA anastomosis. However, cerebral hyperperfusion, alone, cannot explain postoperative ICH. First, all patients had focal neurological deficits such as aphasia, without headache, eye and face pain, vomiting or seizures. Second, transcranial Doppler results showed that postoperative middle cerebral artery velocity was increased < 100% in the operated hemisphere. Postoperative CT did not reveal diffuse or patchy white matter edema or a mass ipsilateral to the STA-MCA bypass. Third, all patients had ICH even though blood pressure was controlled continuously postoperatively.

All five patients had chronic ischemic lesions and diminished cerebrovascular reactivity in the anastomosis hemisphere prior to STA-MCA bypass. There were no symptoms prior to the presence of hemorrhage and only slight symptoms related to ICH thereafter.

The site of hemorrhage was near the anastomosis site. Therefore, focal cerebral hyperperfusion and ischemic reperfusion can result in ICH after STA-MCA anastomosis in steno-occlusive cerebrovascular disease[13]. Przybylski *et al* [8] reported that a small left frontal hemorrhage invaded a previous infarction. In steno-occlusive cerebrovascular diseases, focal brain tissue suffers from chronic ischemic and cerebral hypoperfusion, triggering a subsequent pathogenetic cascade. With chronic cere-

bral hypoperfusion, capillaries increase because of angiogenesis, but they are weak and vulnerable to rupture by distending forces[14], especially with collateral circulation as seen in moyamoya disease[15-16].

Nitric oxide accumulates due to ischemic stimulation and causes vasodilation and increased permeability of focal cerebral vessels[17]. During temporary clamping of the middle cerebral artery, free radicals are produced which damage cerebrovascular endothelium[13, 18-19], and carbon dioxide concentration increases[20]. All of these factors lead to reperfusion injury[21] in brain tissue and hemorrhage in the attenuated vessels when normal perfusion is restored or focal hyperperfusion occurs after STA-MCA anastomosis. Diminished cerebrovascular reactivity also plays an important role in postoperative hemorrhage. Perko *et al* [22] found cerebrovascular reactivity was much lower in males than females, and in the anterior cerebral circulation than in the posterior cerebral circulation. All hemorrhages in our cases occurred in males in the anterior cerebral circulation, and all had diminished cerebrovascular reactivity. Therefore, focal hyperperfusion, ischemic lesions and diminished cerebrovascular reactivity explain the causes of the postoperative ICH after STA-MCA anastomosis.

How do we prevent postoperative ICH after STA-MCA bypass? Blood pressure should be strictly controlled because: (1) Cerebral blood flow is pressure-dependent in patients with diminished cerebrovascular reactivity. (2) Reduction of blood pressure can control hyperperfusion symptoms[23] and decrease middle cerebral artery velocity ipsilateral to the carotid endarterectomy. (3) Strict blood pressure control in selected patients has been associated with a decreased rate of ICH after carotid endarterectomy[24-26]. It is also important to adequately replenish fluid volume simultaneously. In a randomized controlled trial, antioxidants were beneficial in the treatment of acute stroke[27]. Free radical scavengers ameliorated ischemia-reperfusion injury and prevented post-ischemic hyperperfusion. Edaravone, a free radical scavenger, inhibits lipid peroxidation and vascular endothelial cell injury and ameliorates tissue injury and brain edema[28-30]. We found that postoperative ICH was more likely in patients with focal hyperperfusion, ischemic lesions and diminished cerebrovascular reactivity. Therefore, after bypass surgery, free radical scavengers, blood pressure control, and strict monitoring of life signs should be initiated as soon as possible. The use of free radical scavengers and blood pressure control could be beneficial therapies after postoperative ICH. Additionally, surgical removal of the hemorrhage is necessary as the mass effect is life-threatening. In this study, cases 2–5 underwent surgery as soon as possible and recovered well.

In conclusion, postoperative ICH is a rare complication following STA-MCA bypass, occurring 1–4 days after the surgery. Focal hyperperfusion, ischemic lesions and diminished cerebrovascular reactivity are the possible features in patients with ICH following STA-MCA bypass and it is helpful for us to understand the underlying mechanisms. Blood pressure control and free radical scavenger use can prevent postoperative ICH after STA-MCA anastomosis.

SUBJECTS AND METHODS

Design

A retrospective study.

Time and setting

The study was performed in Xuanwu Hospital of Capital Medical University, China from January 2005 to December 2011.

Subjects

In total, the records of 124 patients with steno-occlusive cerebrovascular diseases who received superficial temporal artery-middle cerebral artery bypass were retrospectively reviewed. These patients met the bypass criteria established by the extracranial-intracranial arterial bypass study (EC-IC Bypass Study) in 1985[31], and showed diminished cerebrovascular reactivity (less than 30%)[32].

Patents with postoperative ICH were included according to the following criteria: (1) Patients exhibited postoperative ICH within 1 month after STA-MCA anastomosis. (2) ICH appeared in the ipsilateral hemisphere after STA-MCA bypass.

Patients with subdural or extradural hemorrhage, or no ICH, or ICH in the hemisphere contralateral to the bypass were excluded. Consequently, five patients with postoperative ICH after STA-MCA were included. The average age was 46.2 ± 4.9 years (range, 41 to 53 years old), and all were male. Four patients suffered from atherosclerotic steno-occlusive cerebrovascular diseases, and one patient had moyamoya disease.

Methods

We investigated the inclusion criteria for STA-MCA bypass, concomitant diseases, preoperative check-lists, surgical procedure, and perioperative management. All patients were transferred to the intensive care unit after regaining consciousness following anesthesia. Blood pressure was controlled with intravenous medication if elevated. On the first day after bypass, all patients received brain CT and transcranial Doppler scanning. The preoperative and postoperative middle cerebral artery velocities in the distal M1 segment (insonation depth

ranging from 40 to 60 mm) were recorded and compared. The number of donor branches of the superficial temporal artery and features of ICH were recorded in the surgical records. At discharge, the patients were assessed using the Glasgow Outcome Score (GOS)[33]. The possible features of postoperative ICH patients were summarized.

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Conflicts of interest: None declared.

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