Treatment of Large and Giant Middle Cerebral Artery Aneurysms: Risk Factors for Unfavorable Outcomes

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■ OBJECTIVE: **This study aimed to assess the clinical and radiologic outcomes after neurosurgical treatment of large and giant aneurysms of the middle cerebral artery (MCA). In addition, we aimed to identify risk factors for unfavorable outcomes.**

■ METHODS: **This retrospective study included 105 patients with 106 large or giant MCA aneurysms treated with neurosurgical methods, including microsurgery and endovascular treatment, over a 15-year period.**

■ RESULTS: **The mean aneurysm size was 15.3 ± 7.1 mm. Ten (9.4%) were giant aneurysms. The MCA bifurcation was the most common aneurysm site, followed by the MCA trunk and distal MCA. Aneurysm clipping was the most common treatment method, followed by clipping or trapping with bypass surgery and endovascular treatment. However, acute cerebral infarction was the most common complication (16.0%), poor outcomes (modified Rankin Scale score, 3–6) developed in 12.3% of aneurysms after treatment, and 6.6% of treated aneurysms needed retreatment. Multivariate analysis showed that independent risk factors for acute cerebral infarction after treatment were aneurysms located on the MCA trunk and 2 or more underlying diseases. Initial presentation with subarachnoid hemorrhage and complications during treatment were independent risk factors for poor outcomes. In addition, endosaccular coiling was an independent risk factor for retreatment.**

■ CONCLUSIONS: **Neurosurgical management should be considered a priority for large and giant MCA aneurysms because of the high rupture rate and clinical symptoms. However, treatment outcomes remain unsatisfactory. Therefore, tailored management with consideration of risk factors for unfavorable outcomes should be implemented.**

INTRODUCTION

Unruptured intracranial aneurysms originating from the middle cerebral artery (MCA) account for approximately 29%–41.4% of all unruptured intracranial aneurysms,[1-3] and ruptured MCA aneurysms account for approximately 14.1%–19% of all ruptured aneurysms.[4,5] Large (10–25 mm in diameter) and giant (≥25 mm in diameter) MCA aneurysms are not uncommon in clinical practice and account for 9.8% of all MCA aneurysms.[6]

Patients with large or giant MCA aneurysms may present with several clinical symptoms, including intracranial hemorrhage, headache, focal neurologic deficit caused by mass effect, and seizure or cerebral ischemia; however, aneurysms may also be identified incidentally.[7-10] Previous studies have shown high

Key words
- Cerebral revascularization
- Clip
- Endovascular procedure
- Giant intracranial aneurysm
- Microsurgery
- Middle cerebral artery

Abbreviations and Acronyms
CI: Confidence interval
CT: Computed tomography
DM: Diabetes mellitus
ECB: Early cortical branch
ICH: Intracerebral hemorrhage
LSA: Lenticulostriate artery
MCA: Middle cerebral artery
MR: Magnetic resonance
mRS: Modified Rankin Scale
OR: Odds ratio
PED: Pipeline embolization device
RA: Radial artery
SAH: Subarachnoid hemorrhage
STA: Superficial temporal artery
TFCA: Transfemoral cerebral angiography
UCAS Japan: Unruptured Cerebral Aneurysm Study of Japan

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rupture rates of large and giant MCA aneurysms. UCAS Japan (Unruptured Cerebral Aneurysm Study of Japan)[11] reported that the annual rupture rates of large and giant MCA aneurysms were 4.11% and 16.87%, respectively. In addition, ISUIA (International Study of Unruptured Intracranial Aneurysms)[2] determined that the 5-year cumulative rupture rates for patients without a history of subarachnoid hemorrhage (SAH) who had aneurysms located at the internal carotid artery, anterior communicating or anterior cerebral artery, or MCA were 14.5% for aneurysms with a diameter of 13–24 mm and 40% for aneurysms with a diameter of ≥25 mm. Therefore, neurosurgical management should be considered to prevent rupture or rebleeding and alleviate symptoms caused by mass effect.

These aneurysms have unfavorable characteristics, including irregular morphology such as a fusiform or giant serpentine shape, large or giant size, intramural thrombus formation, calcification, and incorporation of important arterial branches, which often makes neurosurgical treatment difficult.[7,9] Therefore, some large and giant aneurysms are unsuitable for aneurysm neck clipping and endosaccular coiling. Various other neurosurgical techniques such as trapping with extracranial-intracranial bypass surgery, aneurysm thrombectomy with clip reconstruction, aneurysm excision with an in situ bypass, combined endovascular treatment and bypass surgery, and pipeline embolization devices (PEDs) have thus far been used to manage these aneurysms.[7,9,10,12,13] However, residual aneurysm after treatment, recurrence, retreatment, treatment-related complications, and unfavorable outcomes are common during and after the treatment of large and giant MCA aneurysms.[7,9,10,14]

Most previous studies involved small case series of large and giant MCA aneurysms and described only clinical outcomes. In the present study, we retrospectively reviewed our single-center clinical experience with neurosurgical treatment of large and giant MCA aneurysms over a 15-year period. We also analyzed clinical outcomes to identify the incidence of and independent risk factors associated with treatment-related complications and unfavorable outcomes.

METHODS

This study was approved by our institutional review board before data collection began.

Inclusion Criteria

All consecutive patients treated for large or giant MCA aneurysms at our institution between January 2001 and December 2015 were identified by a retrospective chart review. The inclusion criteria were as follows: 1) diagnosis of MCA aneurysm; 2) aneurysm size ≥10 mm (a large aneurysm was defined as 10–25 mm maximum diameter and a giant aneurysm as ≥25 mm maximum diameter); 3) patients who underwent neurosurgical treatment including aneurysm clipping, trapping or clipping with extracranial-intracranial bypass surgery, and endovascular treatment; and 4) patients with a sufficient clinical and imaging follow-up period (>6 months). Patients with large and giant aneurysms as a result of secondary causes such as arteriovenous malformation, moyamoya disease, infectious aneurysm, and trauma were excluded from this study.

Diagnosis and Classification of Large and Giant MCA Aneurysms

Computed tomography (CT), magnetic resonance (MR) imaging, and transfemoral cerebral angiography (TFCA) were performed for all patients to diagnose large or giant MCA aneurysms and to determine the presence of intracranial hemorrhage or other intracranial lesions. The aneurysm size before neurosurgical treatment was measured using TFCA or MR imaging and was reported as maximum diameter.

To define the MCA bifurcation, we usually followed the method of Elsharkawy et al.[15] using three-dimensional CT angiography or conventional angiography and three-dimensional volume-rendered images.[16] Elsharkawy et al.[15] defined MCA bifurcation as the detection of the insular trunks of the MCA based on their posterior superior direction and their course along the insular surface. These trunks were then followed in the proximal direction until the point at which they met, and this convergence point was defined as the main MCA bifurcation. Based on this definition, MCA aneurysms in this study fell into 3 main groups: MCA trunk aneurysms, MCA bifurcation aneurysms, and distal MCA aneurysms. MCA trunk aneurysms were subcategorized into 3 groups: 1) the early cortical branch (ECB) group that included aneurysms that originated from the branching site of the early cortical artery; 2) the lateral lenticulostriate artery (LSA) group, which included aneurysms that incorporated the lateral LSA; and 3) the ECB and lateral LSA group, which included aneurysms that incorporated both the lateral LSA and ECB.

In addition, aneurysms were categorized according to their shape into saccular, fusiform, and giant serpentine aneurysms.

Neurosurgical Treatment

Large and giant MCA aneurysms were categorized into 3 groups according to the neurosurgical modalities used for treatment: an aneurysm clipping group, a bypass group, and an endovascular treatment group. The aneurysm clipping group included all cases that were treated with only clips, such as aneurysm neck clipping (**Figure 1**) and aneurysm thrombectomy with clip reconstruction (**Figure 2**). During aneurysm clipping, temporary clipping times were <3 minutes for each temporary clipping, with the next temporary clipping performed more than 3 minutes after removing the previous temporary clip. The bypass group included modalities that used trapping or clipping of the aneurysm with extracranial-intracranial bypass surgery (**Figures 3** and **4**). We used various bypass techniques according to the location of the aneurysm and incorporated vessels, with the types of bypass surgery as follows: external carotid artery–radial artery (RA)-M2 segment of MCA bypass, proximal superficial temporal artery (STA)-RA-M2 segment bypass,[17] and STA-MCA bypass. The endovascular treatment group included endosaccular coiling with or without stent assistance (**Figure 5**). All neurosurgical treatments were performed under general anesthesia. The choice of neurosurgical treatment was determined by the aneurysm and patient characteristics, initial neurological status, and surgeon's preference.

Adenosine-induced transient asystole was occasionally used in cases in which temporary clipping was not possible because of the size of the aneurysm or severe atherosclerosis of the parent artery during clipping of the aneurysm.[18] Intraoperative micro-Doppler