Microsurgical Clipping of Unruptured Middle Cerebral Artery Bifurcation Aneurysms: Incidence of and Risk Factors for Procedure-Related Complications

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■ OBJECTIVE: **To report our experiences in microsurgical clipping of unruptured middle cerebral artery (MCA) bifurcation aneurysms and to evaluate the incidence of and risk factors for procedure-related complications.**

■ METHODS: **The study comprised 416 patients treated between March 2003 and February 2014. All patients met the following criteria: 1) microsurgical clipping of an unruptured MCA bifurcation aneurysm was performed, and 2) clinical and radiographic follow-up data were available including preoperative digital subtraction angiography. The incidence of and risk factors for procedure-related complications were retrospectively evaluated.**

■ RESULTS: **Procedure-related complications occurred in 15 (3.6%) patients, including asymptomatic complications in 10 (2.4%) patients and symptomatic complications in 5 (1.2%) patients. Multivariate logistic regression analysis showed that posteroinferior projection of the aneurysm (odds ratio = 2.814, 95% confidence interval = 0.995–6.471, *P* = 0.042), distance between the internal carotid artery bifurcation and the MCA bifurcation (Dt) in a linear line (odds ratio = 1.813, 95% confidence interval = 0.808–6.173, *P* = 0.043), and horizontal angle between the vertical line to the base of the skull and Dt (odds ratio = 2.046, 95% confidence interval = 1.048–10.822, *P* = 0.048) were independent risk factors for procedure-related complications.**

■ CONCLUSIONS: **When performing clipping of unruptured MCA bifurcation aneurysms, the procedure-related complication rate was 3.6%. Patients with MCA bifurcation aneurysms with posteroinferior projection, shorter Dt, and larger horizontal angle may be at a higher risk of procedure-related complications when performing microsurgical clipping.**

INTRODUCTION

Most middle cerebral artery (MCA) aneurysms are surgically accessible with limited brain retraction, and the surgical outcomes have been improved in recent years (3, 6, 9, 14). Although endovascular treatment (EVT) of MCA aneurysms has been reported as a feasible, safe, and durable approach in studies with midterm and long-term follow-up (2, 12, 13), the anatomic configuration of MCA bifurcation aneurysm is frequently unfavorable for EVT (11), often requiring complex EVT techniques, such as multiple-microcatheter, stent-assisted, and balloon-assisted techniques. Among surgically treated unruptured MCA bifurcation aneurysms, procedure-related complications are encountered that may cause minor or major morbidities or both. It is important to reduce the morbidity associated with microsurgical approaches because the surgical risks should not exceed the natural risks. To this end, preoperative awareness of risk factors for procedure-related complications is highly beneficial. The purpose of this study is to describe our experiences in microsurgical clipping of unruptured MCA bifurcation aneurysms and to evaluate the incidence of and risk factors for procedure-related complications so that

Key words
- Complications
- Intracranial aneurysm
- Microsurgical clipping
- Middle cerebral artery
- Predictors
- Unruptured aneurysm

Abbreviations and Acronyms
CI: Confidence interval
CT: Computed tomography
DSA: Digital subtraction angiography
Dt: Distance between internal carotid artery bifurcation and middle cerebral artery bifurcation
EVT: Endovascular treatment
ICA: Internal carotid artery
ICH: Intracerebral hemorrhage
LSA: Lenticulostriate artery
MCA: Middle cerebral artery

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neurosurgeons can be aware of risk factors preoperatively to prevent procedure-related complications.

MATERIALS AND METHODS

This retrospective study was approved by our institutional review board, and the requirement for informed consent was waived. Patient data were gathered from 4 hospitals where 5 neurosurgeons, all alumni of a single institution, operated on patients using almost the same surgical techniques, including a standard pterional (frontotemporal) craniotomy and arachnoid dissection (transsylvian approach). Veins crossing the sylvian fissure (bridging veins) were coagulated and sacrificed if they limited retraction of the frontal lobe. Our prospectively collected database contained a series of 1652 patients with unruptured intracranial aneurysms treated by microsurgical clipping from March 2003 to February 2014. Among these patients, 557 had aneurysms on the MCA. This study included 416 patients (male-to-female ratio, 163:253; mean age, 57.2 years ± 11.2), and all patients met the following criteria: 1) microsurgical clipping of an unruptured MCA bifurcation aneurysm was performed, and 2) clinical and radiographic follow-up data were available including preoperative digital subtraction angiography (DSA) for a minimum of at least 1 year. There were 147 patients who were excluded from the study for the following reasons: 1) distal MCA (distal to MCA bifurcation) or M1 aneurysms, such as aneurysms originated from the lenticulostriate artery (LSA), the anterior temporal artery, or early frontal branches of the MCA ($n = 73$); 2) unruptured MCA bifurcation aneurysms treated simultaneously with other ruptured aneurysms ($n = 54$); and 3) loss to follow-up within 12 months ($n = 20$). We retrospectively reviewed radiographs, medical records, and surgical operation videos.

The anatomic architecture of M1 and aneurysms was evaluated on preoperative DSA. On DSA, the Towne anteroposterior view was controlled at 30° from the orbitomeatal line. We determined that M1 was located between the bifurcation of the internal carotid artery (ICA) and the main bifurcation of the MCA based on previous studies (5, 15). We measured the distance between the bifurcation of the ICA and the main bifurcation of the MCA (Dt) in a straight line (**Figure 1A**). The horizontal angle was measured as the angle between the vertical line to the base of the skull and the Dt (**Figure 1B**). The recurrent branch of the LSA from the MCA bifurcation was recorded (**Figure 1C**). According to the projection of the dome, aneurysm direction was noted as anterior, superior, inferior, or posterior projection (**Figure 1D**). The size of each aneurysm was measured using the longest axis.

Patient factors, including age, sex, hypertension, diabetes, smoking, coronary artery disease, and previous subarachnoid hemorrhage from another aneurysm; aneurysm characteristics, including location (right or left), dome size, neck size, perforators from the neck, dome projection, Dt, horizontal angle, and thrombus in aneurysm; and surgical factors, including atherosclerosis of aneurysm, atherosclerosis of the parent artery, bridging vein coagulation during sylvian dissection, and temporary clipping, were evaluated to identify risk factors for procedure-related complications. Procedure-related complications included postoperative epidural hematomas requiring surgical evacuation, intracerebral hemorrhage (ICH), parenchymal low density on postoperative computed tomography (CT) scan, and neurologic deterioration compared with preoperative conditions. Postoperative CT scans were performed either immediately or 1 day after the surgery and were reviewed by 2 independent investigators. We averaged the measured values of the Dt and the horizontal angle. Clinical outcomes were assessed based on the modified Rankin Scale and evaluated by an independent investigator who was not involved in the care of the patients.

All statistical analyses were performed using IBM SPSS Statistics version 19.0 (IBM Corp., Armonk, New York, USA) in consultation with a biostatistician. Mann-Whitney U tests were used for numeric variables. χ^2 tests or Fisher exact tests were used for nominal variables. Univariate analysis was performed to determine the associations of procedure-related complications with other factors. Multivariate logistic regression analysis was performed on variables with an unadjusted effect and a P value < 0.10 on univariate analysis to determine independent associations of procedure-related complications with other factors. A P value < 0.05 for a 95% confidence interval (CI) was considered statistically significant.

RESULTS

Of 416 patients included in this study, 52 (12.3%) patients had a previous history of subarachnoid hemorrhage from other aneurysms, and 180 (43.3%) patients had MCA bifurcation aneurysms on the left side. There were 3 (0.7%) giant aneurysms (>25 mm), 28 (6.7%) large aneurysms (10–25 mm), and 385 (92.6%) small aneurysms (<10 mm). There were 3 (0.7%) aneurysms with intraaneurysmal thrombus. Multiple aneurysms were noted in 40 (9.6%) patients. There were 259 (62.3%) aneurysms projected in the anterosuperior direction and 157 (37.7%) aneurysms projected in the posteroinferior direction. There was no bleeding from any of the treated aneurysms during clinical follow-up.

Overall, procedure-related complications occurred in 15 (3.6%) patients; asymptomatic complications were noted in 10 (2.4%) patients, and symptomatic complications were noted in 5 (1.2%) patients. Of the symptomatic patients, 2 showed modified Rankin scale 2 and 3 showed modified Rankin scale 3 on clinical follow-up examinations. **Table 1** presents the details for all 15 patients with procedure-related complications. Complications were frontal low density on postoperative CT scan in 8 patients, ICH in 5 patients (3 frontal ICH and 2 temporal ICH), and epidural hematoma, which was immediately removed, in 2 patients.

Posteroinferior projection of the aneurysm, Dt, horizontal angle, and bridging vein coagulation during sylvian dissection with a P value < 0.10 on univariate analysis ($P = 0.036$, $P = 0.030$, $P = 0.045$, and $P = 0.033$) were included in multivariate logistic regression analysis to evaluate their independent associations with procedure-related complications and other factors. Posteroinferior projection of the aneurysm (odds ratio = 2.814, 95% CI = 0.995–6.471, $P = 0.042$), Dt (odds ratio = 1.813, 95% CI = 0.808–6.173, $P = 0.043$), and horizontal angle (odds ratio = 2.046, 95% CI = 1.048–10.822, $P = 0.048$) remained as independent risk factors for procedure-related complications according to multivariate logistic regression analysis (**Table 2**).

DISCUSSION

Microsurgical clipping of MCA bifurcation aneurysms is generally thought to be easier than surgery of aneurysms in other sites.