의학석사 학위논문

Comparison of unilateral and bilateral craniotomy for the treatment of bilateral middle cerebral artery aneurysms: anatomical and clinical parameters and surgical outcomes

양측성 중대뇌동맥 동맥류 결찰술의 단측 개두술과 양측 개두술의 비교 연구

2018년 02월

서울대학교 대학원

의학과 신경외과학 전공

조 민 재

의학석사 학위논문

Comparison of unilateral and bilateral craniotomy for the treatment of bilateral middle cerebral artery aneurysms: anatomical and clinical parameters and surgical outcomes

양측성 중대뇌동맥 동맥류 결찰술의 단측 개두술과 양측 개두술의 비교 연구

2018년 02월

서울대학교 대학원

의학과 신경외과학 전공

조 민 재

ABSTRACT

Comparison of unilateral and bilateral craniotomy for the treatment of bilateral middle cerebral artery aneurysms: anatomical and clinical parameters and surgical outcomes

Min Jai Cho

Department of Medicine, Neurosurgery

The Graduate School

Seoul National University

Objective: To compare two craniotomy approaches (unilateral and bilateral) in terms of anatomical and clinical parameters and surgical outcomes.

Methods: From January 2011 to December 2014, at the Bundang Seoul National

University Hospital, 19 patients with bilateral unruptured middle cerebral artery (MCA) aneurysms were treated with unilateral craniotomy (group 1) and 10 patients were treated with bilateral mini-craniotomy (group 2). We compared demographic data, characteristics of aneurysms, radiological and clinical parameters, postoperative complications, and surgical outcomes between the groups.

Results: No statistically significant differences were found in aneurysm characteristics between the two groups. Radiological parameters did not have any influence on surgical outcomes or the incidence of postoperative complications. Group 1 had a higher incidence of olfactory dysfunction (11/19, 58%) and residual neck at the contralateral aneurysm (10/19, 53%), while group 2 did not have olfactory dysfunction or residual neck at the contralateral aneurysm. There was a significant difference in the frequency of postoperative olfactory dysfunction between the two groups ($P = 0.003$).

All patients in group 2 had good surgical outcomes (modified Rankin scale 0). The length of the hospital stay was similar in both groups.

Conclusion: Bilateral mini-craniotomy for the treatment of bilateral MCA aneurysms was associated with better surgical outcomes and fewer complications. Bilateral mini-craniotomy does not require as much retraction of the frontal lobe to apply a clip completely at the contralateral aneurysm. Therefore, it represents a safe and effective therapeutic option for unruptured bilateral MCA aneurysms.

Key words: bilateral craniotomy, bilateral middle cerebral artery aneurysms, postoperative olfactory dysfunction, unilateral craniotomy

Student number: 2016-21944

Contents

List of Tables

List of Figures

INTRODUCTION

The incidence of bilateral middle cerebral artery (MCA) aneurysms among intracranial aneurysms is approximately 1%. (1-3) Bilateral MCA aneurysms have been reported as one of the most common types of multiple aneurysms. (4) Typically, MCA aneurysms have a wide neck, predominantly incorporate one or both insular segments of the middle cerebral artery (M2) branches, and lie at the edge of the brain. Thus, microsurgical clipping is preferable over endovascular coiling. Between the two microsurgical approaches, the unilateral approach has several advantages, such as reduced surgical time, lower risk of complications, and reduced costs and length of hospital stay, in some patients. (5) Bilateral craniotomy allows surgical clipping to be performed in one stage. Moreover, it is less complicated than the unilateral approach in terms of brain retraction. However, there is no consensus regarding a standard treatment protocol for bilateral MCA aneurysms.

With the above in mind, the purpose of this study was to compare these two approaches (unilateral vs. bilateral) in terms of demographic data, aneurysm characteristics, anatomical and clinical parameters, postoperative complications, and surgical outcomes. The primary concern in cases of unruptured intracranial aneurysms is the avoidance of complications. By comparing surgical and clinical outcomes between the approaches (particularly in terms of postoperative olfactory dysfunction and residual contralateral MCA aneurysm), we sought to identify the optimal treatment for bilateral MCA aneurysms.

METHODS

Between January 2011 and December 2014, microsurgical clipping of 933 aneurysms was performed at the Bundang Seoul National University Hospital. Among these cases, 55 patients had bilateral intracranial aneurysms. Patients with bilateral aneurysms in locations other than the MCA were excluded. A total of 29 patients with bilateral MCA aneurysms were surgically treated at our hospital. A total of 19 patients underwent a unilateral craniotomy (group 1) and 10 patients underwent consecutive bilateral mini frontolateral craniotomy in one stage (group 2). When the size of the MCA aneurysm was > 4 mm or < 4 mm with evidence of blebs, microsurgical clipping was performed. Initially, 19 consecutive patients with bilateral MCA aneurysms met these criteria and underwent unilateral craniotomy. In the unilateral approach, the approach side was selected considering the possibility of rupture risk. The approach side was determined by a higher rupture risk of the aneurysm, longer length of the horizontal segment of the middle cerebral artery (M1), and larger size of the MCA aneurysm. Based on these criteria, 13 patients underwent right-sided and six patients underwent left-sided surgery. However, after detection of postoperative olfactory dysfunction and residual contralateral MCA, all patients with bilateral MCA aneurysms who met these criteria underwent bilateral mini-craniotomy. There were no definite indications for different treatment protocols.

Medical records, radiographic images (transfemoral cerebral angiography, brain magnetic resonance angiography, and brain computed tomography angiography [CTA]), intraoperative photographs, videos, and clinical follow-up examination findings were retrospectively analyzed. The angiographic findings of all patients were analyzed before surgery and at postoperative week 1. Following microsurgical clipping, patients underwent brain CTA at postoperative months 1 and 6 to determine whether the clipped aneurysms were re-forming. Olfactory dysfunction was examined through test substances (coffee and alcohol) in the hospital and at an outpatient clinic. Surgical outcomes were evaluated using the modified Rankin Scale (mRS) 6 months after surgery because we hypothesized that neurological deficits do not recover after this time point. Outcomes were compared in terms of postoperative mRS at discharge and at 3 months postoperatively. Statistical analyses were performed using SPSS for Windows (version 22.0, SPSS Inc., Chicago, IL, USA). Between both approaches, categorical variables were compared using Fisher's exact test and the Mann-Whitney U-test. Results with a P value < 0.05 were considered statistically significant. This study received institution review board approval and the need for informed consent was waived.

Surgical method

1) Unilateral craniotomy group (group 1)

A standard pterional craniotomy was used for unilateral MCA aneurysm clipping. The Sylvian fissure was opened widely to obtain a wide working space and a relaxed brain with minimal retraction. The ipsilateral M1 was exposed for proximal control and the aneurysm was clipped. Dissection of the arachnoid was subsequently performed around the ipsilateral optic nerve, chiasm, and interoptic space. The optic nerve and olfactory tract were dissected and released for further frontal lobe retraction. The contralateral carotid cistern, the optico-carotid cistern, and medial part of the Sylvian fissure were opened along the internal carotid artery. The contralateral aneurysm was clipped using brain endoscopy when required (Figure 1, 2).

2) Bilateral craniotomy group (group 2)

A mini frontolateral craniotomy was used for bilateral MCA aneurysm clipping. The patients were placed in the supine position, with their head fixed and rotated 30–45° with neck extension and lateral bending. The incision was made approximately 9 cm behind the hairline. A one-layer skin-galea-muscle flap was made. The temporalis muscle was cut in its superior and anterior sections. One keyhole was opened posteriorly, just below the insertion line of the temporalis muscle. Frontolateral mini-craniotomy was then performed. The mean bone flap was 3 × 3.5 cm in size. After the dura mater was opened using a curvilinear incision and elevated with stitches, the sphenoid ridge was drilled and the Sylvian fissure was opened prior to aneurysm clipping. The dura mater was closed with silk sutures. The bone flap was then fixed with plates and screws before layer-by-layer closure. After rotating the head to the opposite side, the contralateral frontolateral approach was used and the contralateral aneurysm was clipped. (Figure 3, 4)

RESULTS

Demographic data

The demographic data of the included patients are shown in Table 1. Group 1 included 12 women and seven men with a mean age of 58.7 years (range: 42–74 years). Group 2 included seven women and three men with a mean age of 59.5 years (range: 46–68 years). Table 1 presents the medical history characteristics (including the presence of hypertension, hyperlipidemia, diabetes, and smoking) of patients in both groups. There were no statistically significant differences in these factors between the groups.

Radiologic findings

The size, morphology, projections, associated aneurysms, and characteristics of the bilateral MCA aneurysms in both groups are summarized in Table 2. In group 1, all contralateral MCA aneurysms were small (<5mm) or medium (5–10 mm). The dome projections of the contralateral MCA aneurysms were as follows: anterior (n = 3), inferior (n = 5), superior (n = 7), lateral (n = 3), and posterior (n = 1). In group 1, the mean length of the contralateral pre-communicating segment of the anterior cerebral artery (A1) was 14.8 mm (13–18 mm), the length of the contralateral M1 was 14.8 mm (10–22 mm), and the mean distance between both aneurysm necks was 58.7 mm (51–78 mm). Contralateral MCA aneurysm clipping was possible at up to 22 cm of the contralateral M1. In group 2, the mean length of the contralateral A1 was 15.3 mm (13–21 mm), the length of the contralateral M1 was 18 mm (10–32 mm), and the mean distance between both aneurysm necks was 63.4 mm (53–83 mm) (Table 3). There were no statistically significant differences in aneurysm characteristics between the two groups.

Surgical outcomes

In group 1, the mean volume of intraoperative blood loss was 555 mL and the mean operative time was 230 min (145–340 min). In group 2, the mean intraoperative blood loss was 800 mL and the mean operative time was 393 min (290–610 min). The mean duration of hospitalization in the unilateral group was 11.8 days, as compared to 13.3 days in the bilateral group. In the unilateral group, 10 patients (53%) exhibited contralateral residual neck following surgery, although they were minimal (Figure 1). In the bilateral group, none of the patients had a contralateral residual neck (Figure 2). There were statistically significant differences in the occurrence of postoperative contralateral residual necks between the two approaches (P = 0.018). However, all other parameters were not significantly different between the two groups (Table 4). In terms of postoperative complications, in the unilateral group, 11 patients (58%) exhibited olfactory dysfunction, one patient (5%) had visual impairment, and one patient (5%) had intraoperative rupture. In the bilateral group, no patients exhibited olfactory dysfunction, although one patient (10%) had a wound infection and underwent revision surgery. There was a significant difference in the frequency of postoperative olfactory dysfunction between the two groups (P = 0.003).

Clinical outcomes

In the unilateral group, 11 patients had an mRS score of 1 at 6 months postoperatively due to olfactory dysfunction. mRS scores of 2 resulted from postoperative visual impairment. In the bilateral group, all patients had an mRS score of 0 (Table 5).

DISCUSSION

The present study demonstrated that the unilateral approach caused postoperative olfactory dysfunction in 58% (11/19) of patients and resulted in a contralateral residual neck in 53% (10/19) of patients. With the unilateral approach, 18 patients (95%) had an mRS scores of 0 or 1, except for one patient (mRS score: 2). In the bilateral group, all patients exhibited good mRS scores. On comparing the hospitalization period between the groups, there were no significant differences.

Anatomical lengths of M1 and A1

All anatomical lengths were measured with conventional 3D angiography in the present study. The findings demonstrated that the lengths of the contralateral A1 and M1 segments in the unilateral group were 12.9–18 mm and 10–22 mm, respectively. The mean length of the contralateral A1 in the present study was similar to the length reported by Inci et al. (6) and the mean lengths of the M1 segment in this study were greater than those demonstrated by Inci et al.6 However, the mean length of M1 was shorter than that reported in a study by Andrade-Barazarte et al. (5)

In previous studies, the length of contralateral M1 segments was important and the total length of A1+M1 was even more important (6) when selecting patients for the unilateral approach. The results of the present study suggest that the distance between both aneurysm necks had no significant relationship with surgical outcomes and postoperative complications. The most notable point was that we could apply the clip on the contralateral aneurysm at up to 22 mm of the M1 length, as compared to 14 mm reported by Ohiro et al. (7)

Contralateral residual neck

Most patients in the unilateral approach group (11/19) had contralateral residual neck following surgery. However, the residual growth was minimal, and no regrowth was detected after a 2-year follow-up using brain CTA. It was reported that laterally and superiorly directing contralateral aneurysms were the most difficult to clip. It was also difficult to apply clips to laterally, superiorly, and posteriorly directing contralateral aneurysms. However, because of the small number of cases in the present study, the development of the contralateral residual neck had no significant relationship with the direction of aneurysms (P = 0.35). (8)

Postoperative olfactory dysfunction

In the unilateral approach group, 18 patients (95%) had mRS scores of 0 or 1, with one patient exhibiting an mRS score of 2. In the bilateral group, all patients had good mRS scores. Good surgical outcomes (mRS scores: 0–2) when using the unilateral approach for bilateral MCA aneurysms have been reported in 83–91% of patients, (5, 6, 8, 9) whereas the present study demonstrated good outcomes in 100% of patients. However, in the present study, 58% (11/19) patients who underwent the unilateral approach exhibited olfactory dysfunction.

The incidence of postoperative olfactory dysfunction following the unilateral approach in the present study was higher than that reported by Juha et al. (21%) (5), but similar to that reported by Park et al. (58%). (10) In the present study, for the first 10 cases in the unilateral group, we did not separate the olfactory tract from the frontal base. Among these patients, six (60%) exhibited postoperative olfactory dysfunction. In the subsequent nine patients, the olfactory tract was dissected and released from the frontal base. Despite this procedure, four patients (44%) presented with olfactory dysfunction. Although the rate of olfactory dysfunction was decreased by 16% when using the latter method, the final postoperative olfactory dysfunction rate was still high (58%). This high occurrence of postoperative olfactory dysfunction may have been caused by excessive frontal lobe retraction. Although the olfactory tract was dissected from the frontal lobe and released, the incidence of postoperative olfactory dysfunction was higher than predicted. In the present study, the occurrence of olfactory dysfunction was not related to contralateral MCA length, as in the study by Park et al., (10) and no association with aneurysm characteristics, age, or anatomical parameters was detected.

Postoperative olfactory dysfunction occurs frequently when using the pterional approach after microsurgical clipping of the anterior circulation aneurysm, particularly when using the contralateral approach. (6, 11-13) Therefore, preserving the olfactory nerve must be prioritized during the unilateral approach. The cause of olfactory dysfunction via the pterional approach is olfactory tract injury due to sustained frontal lobe retraction and destruction of the vessels supplying the olfactory tract. (14) To preserve the olfactory tract, the tract should be delicately and thoroughly dissected from the arachnoid attachments with sharp instruments while avoiding any traction on the anterior portion of the olfactory tract. This redundant mobilization of the olfactory tract enables surgeons to retract the frontal lobe easily without damaging the tract. Excessive and prolonged pressure should be avoided during frontal lobe retraction to preserve microcirculation to the tract. To achieve this, effort must be made to not use brain retractors. (13, 15)

One of the most notable findings of the present study was that patients who underwent the unilateral approach did not complain of changes in their sense of smell during the immediate postoperative period; however, olfactory dysfunction occurred after discharge. The mean period of postoperative hyposmia onset was 2–3 months. Patients complained of hyposmia or anosmia at outpatient clinics; moreover, once the patient exhibited olfactory dysfunction, the olfactory function did not improve. Therefore, the possibility of olfactory nerve injury should be considered, though the patients did not complain of hyposmia or anosmia during the immediate postoperative period in the unilateral approach.

Comparison of the two approaches

Unilateral approach

Advantages of the unilateral approach include sparing of the secondary craniotomy, reducing the days in hospital and the cost of treatment, improved cosmetic appearance due to single craniotomy, and decreased intraoperative blood loss. Other studies have reported shortening of the surgical time by 43–46% when performing the unilateral approach over the bilateral approach during surgical clipping of bilateral MCA aneurysms. (5, 6) However, a disadvantage of the unilateral approach is the strong possibility of olfactory dysfunction and optic nerve injury due to brain retraction when crossing the midline to access the contralateral aneurysm. Furthermore, before surgery, patients must be carefully selected to undergo microsurgical clipping of bilateral MCA aneurysms since some directions of contralateral MCA aneurysm are difficult to clip. A thorough preoperative analysis of the exact localization, size, and characteristics of all aneurysms is important. (8, 16) Moreover, if the contralateral aneurysm ruptures during the intraoperative period, it is difficult to control the bleeding.

Bilateral mini-craniotomy

The advantage of bilateral mini-craniotomy is that patients are not selected as with the unilateral approach; therefore, more complex aneurysms are treated. In addition, the working space is wider and less deep than with the unilateral approach for treating contralateral MCA aneurysms, and the frontal lobe is not aggressively retracted. As a result, olfactory tract and optic nerve injuries are rare. However, the bilateral approach is associated with longer surgical duration, more blood loss, and more cerebrospinal fluid loss than the unilateral approach. Therefore, there is an increased risk of epidural hemorrhage, subdural hemorrhage, infection, and seizure during the immediate postoperative period. (17, 18) However, in the present study, no patients experienced postoperative seizures. One patient had postoperative epidural hemorrhage, but the extent of the hemorrhage was minimal and it was absorbed naturally. Another patient exhibited a postoperative contralateral subdural hemorrhage, which improved after conservative management. There was one case of epidural empyema in which the patient underwent revision surgery with no subsequent neurological deficit. There was no significant difference in infection rates between the groups ($P = 0.35$).

The most important aim during microsurgical clipping of an unruptured aneurysm is avoiding complications and abiding by the “do no harm to the patient” rule. Considering the postoperative olfactory dysfunction and contralateral residual neck observed following the unilateral approach, the optimal treatment of bilateral MCA aneurysms appears to be bilateral mini-craniotomy. Therefore, we have changed our protocol and prefer the bilateral mini frontolateral craniotomy when microsurgically clipping unruptured bilateral MCA aneurysms.

Limitations

This study has some limitations. First, data were collected retrospectively from cases treated by a single surgeon from one institution. Second, we did not measure olfactory function objectively. Moreover, olfactory function was measured using only alcohol and coffee as test substances, and the degree of olfactory function was determined in an outpatient clinic. Third, the size of the study population was small.

CONCLUSION

The unilateral approach leads to increased postoperative olfactory dysfunction (11/19; 58%) and residual neck of the contralateral aneurysm (10/19; 53%). Therefore, we changed our preferred surgical method from a unilateral approach to bilateral mini frontolateral craniotomy when treating bilateral MCA aneurysms after recognizing the surgical outcomes and complications associated with both approaches. Bilateral mini-craniotomy provides a relatively wide and less deep working space than the unilateral approach; thus, there is no need to retract the frontal lobe to apply a clip successfully on contralateral aneurysms. In addition, the length of hospital stay is similar in both approaches. Bilateral mini-craniotomy is a safe and effective therapeutic option for unruptured bilateral MCA aneurysms.

REFERENCES

1. Shin BG, Kim JS, Hong SC. Single-stage operation for bilateral middle cerebral artery aneurysms. *Acta Neurochir (Wien).* Jan 2005;147(1):33-38; discussion 38.

2. Khursheed N, Bhattacharya RN, Nair S, Menon G, Rao RM. Middle Cerebral Artery Aneurysms An Institutional Experience in a South Indian Population. *Neurosurgery Quarterly.* Dec 2008;18(4):246-250.

3. Pereira RS, Casulari L. Surgical treatment of bilateral multiple intracranial aneurysms: review of a personal experience in 69 cases. *Journal of neurosurgical sciences.* 2006;50(1):1.

4. Rinne J, Hernesniemi J, Niskanen M, Vapalahti M. Analysis of 561 patients with 690 middle cerebral artery aneurysms: anatomic and clinical features as correlated to management outcome. *Neurosurgery.*

1996;38(1):2-11.

5. Andrade-Barazarte H, Kivelev J, Goehre F, et al. Contralateral Approach to Bilateral Middle Cerebral Artery Aneurysms: Comparative Study, Angiographic Analysis, and Surgical Results. *Neurosurgery.* Dec 2015;77(6):916-926; discussion 926.

6. Inci S, Akbay A, Ozgen T. Bilateral middle cerebral artery aneurysms: a comparative study of unilateral and bilateral approaches. *Neurosurgical review.* 2012;35(4):505-518.

7. Oshiro EM, Rini DA, Tamargo RJ. Contralateral approaches to bilateral cerebral aneurysms: a microsurgical anatomical study. *J Neurosurg.* Aug 1997;87(2):163-169.

8. Rodriguez-Hernandez A, Gabarros A, Lawton MT. Contralateral clipping of middle cerebral artery aneurysms: rationale, indications, and surgical technique. *Neurosurgery.* Sep 2012;71(1 Suppl Operative):116-123; discussion 123-114.

9. de Sousa AA, Filho MA, Faglioni W, Jr., Carvalho GT. Unilateral pterional approach to bilateral aneurysms of the middle cerebral artery. *Surg Neurol.* 2005;63 Suppl 1:S1-7.

10. Park J, Lee SH, Kang DH, Kim JS. Olfactory dysfunction after ipsilateral and contralateral pterional approaches for cerebral aneurysms. *Neurosurgery.* Oct 2009;65(4):727-732; discussion 732.

11. Wermer MJ, Donswijk M, Greebe P, Verweij BH, Rinkel GJ. Anosmia after aneurysmal subarachnoid hemorrhage. *Neurosurgery.* 2007;61(5):918-923.

12. Aydin IH, Kadioglu HH, Tuzun Y, Kayaoglu CR, Takci E, Ozturk M. Postoperative anosmia after anterior communicating artery aneurysms surgery by the pterional approach. *Minimally invasive neurosurgery : MIN.* Sep 1996;39(3):71-73.

13. Cardali S, Romano A, Angileri FF, et al. Microsurgical anatomic features of the olfactory nerve: relevance to olfaction preservation in the pterional approach. *Neurosurgery.* Jul 2005;57(1 Suppl):17-

21; discussion 17-21.

14. Comert A, Ugur HC, Kahilogullari G, Comert E, Elhan A, Tekdemir I. Microsurgical Anatomy for Intraoperative Preservation of the Olfactory Bulb and Tract. *J Craniofac Surg.* May 2011;22(3):1080-1082.

15. Favre J, Chaffanjon P, Passagia J, Chirossel J. Blood supply of the olfactory nerve. *Surgical and Radiologic Anatomy.* 1995;17(2):133-138.

16. Hopf N, Stadie A, Reisch R. Surgical management of bilateral middle cerebral artery aneurysms via a unilateral supraorbital key-hole craniotomy. *min-Minimally Invasive Neurosurgery.* 2009;52(03):126-131.

17. Korinek AM. Risk factors for neurosurgical site infections after craniotomy: a prospective multicenter study of 2944 patients. The French Study Group of Neurosurgical Infections, the SEHP, and the C-CLIN Paris-Nord. Service Epidemiologie Hygiene et Prevention. *Neurosurgery.* Nov 1997;41(5):1073-1079; discussion 1079-1081.

18. Kim SH, Lee JH, Joo W, et al. Analysis of the risk factors for development of post-operative extradural hematoma after intracranial surgery. *British journal of neurosurgery.* Apr 2015;29(2):243-248.

Table 1. Demographic data		
Variable	**Unilateral group(Group 1)**	**Bilateral group (Group 2)**
Age, years[a]	58.7(42-74)	59.5(46-68)
Sex ratio, F:M	12:7	7:3
Medical history[b]		
Hypertension	14(74)	7(70)
Diabetes	5(26)	2(20)
Dyslipidemia	5(26)	4(40)
Smoking	7(37)	3(30)

[a]Data are presented as the mean (range). [b]Data are presented as the number of patients (%). F: female; M: male;

Table 2. Radiologic characteristics of bilateral MCA aneurysms				
	Group 1		Group 2	
	Ipsilateral aneurysm	Contralateral aneurysm	Ipsilateral aneurysm treated	Contralateral aneurysm
	N (%)	N (%)	N (%)	N (%)
Aneurysm size				
Small, <5 mm	14(74)	18(95)	7(70)	8(80)
Medium,5-10mm	4(21)	1(5)	2(20)	2(20)
Large,>10 mm	1(5)	0(0)	1(10)	0(0)
Shape				
Saccular	10(53)	14(74)	2(20)	7(70)
Atherosclerosis	2(11)	2(11)	0(0)	1(10)
With bleb	6(32)	3(16)	6(60)	2(20)
Mixed	1(5)	0(0)	2(20)	0(0)
Direction				
Anterior	7(37)	3(16)	3(30)	1(10)
Inferior	6(32)	5(26)	1(10)	3(30)
Superior	1(5)	7(37)	1(10)	1(10)
Lateral	5(26)	3(16)	5(50)	5(50)
Posterior	0(0)	1(5)	0(0)	0(0)

Location				
M1	1(5)	2(11)	0(0)	3(30)
MCAB	18(95)	17(89)	10(100)	7(70)
Multiplicity				
Other aneurysms	8		5	

MCA: middle cerebral artery; M1: horizontal segment of middle cerebral artery; MCAB: middle cerebral artery bifurcation;

Table 3. Radiologic parameters			
Parameter (mm)	**Group 1**	**Group 2**	**p value**
Mean length of contralateral A1	15.0 (12.9-18)	15.3 (10-32)	0.43
Mean length of contralateral M1	15.3 (10-22)	18.0 (10-32)	0.09
Distance between both ICAB	31.7 (27-41)	30.2 (25-33)	0.98
Distance between both aneurysm necks	59.2 (51-78)	63.4 (53-83)	0.24
Height of ICA bifurcation	9.6 (5-17)	9.0 (4-12)	0.87

Data are presented as the mean (range). M1: insular segment of middle cerebral artery; A1: pre communicating segment of anterior cerebral artery; ICA: internal carotid artery; ICAB: internal carotid artery bifurcation;

Table 4. Surgical outcomes			
Variable	**Group 1**	**Group 2**	**p Value**
Intraoperative blood loss (mL)	555	1455	0.41
Operative time, mean min (range)	230(145-340)	393 (290-610)	0.55
Mean hospitalization period, (days)	11.8	13.3	
Contralateral residual neck, N (%)	10(53)	0(0)	0.018
Postoperative complications, N (%)			
Ipsilateral asymptomatic infarction	1(5)	1(10)	0.98
Contralateral asymptomatic infarction	1(5)	1(10)	0.98
Olfactory dysfunction	11(58)	0(0)	0.003
Wound infection	0(0)	1(10)	0.66
Visual impairment	1(5)	0(0)	0.83
Ipsilateral ICH	1(5)	0(0)	0.54
Contralateral intraoperative rupture	1(5)	0(0)	0.83

Ipsilateral SDH	1(5)	0(0)	0.80
Contralateral asymptomatic SDH	0(0)	1(10)	0.19
Asymtomatic EDH	0(0)	1(10)	0.40

ICH: intracerebral hemorrhage; SDH: subdural hematoma; EDH: epidural hematoma;

Table 5. Clinical outcomes			
Variable		**Group 1**	**Group 2**
	mRS score	**N (%)**	**N (%)**
At discharge	0	16(84)	10(100)
	1	1(5)	0(0)
	2	2(11)	0(0)
	3	0(0)	0(0)
	4	0(0)	0(0)
	5	0(0)	0(0)
	6	0(0)	0(0)
Postoperative 6 months	0	6(32)	10(100)
	1	11(58)	0(0)
	2	1(5)	0(0)
	3	0(0)	0(0)
	4	0(0)	0(0)
	5	0(0)	0(0)
	6	0(0)	0(0)

mRS: modified Rankin scale;

Figure 1. Unilateral craniotomy for contralateral middle cerebral artery (MCA) aneurysm clipping

A), B) Right pterional craniotomy. After opening the dura and Sylvian cistern, the contralateral optic nerve was observed. C) After frontal lobe retraction, the contralateral M1 was exposed. D) The contralateral MCA bifurcation aneurysm was exposed. E) The aneurysm was clipped.

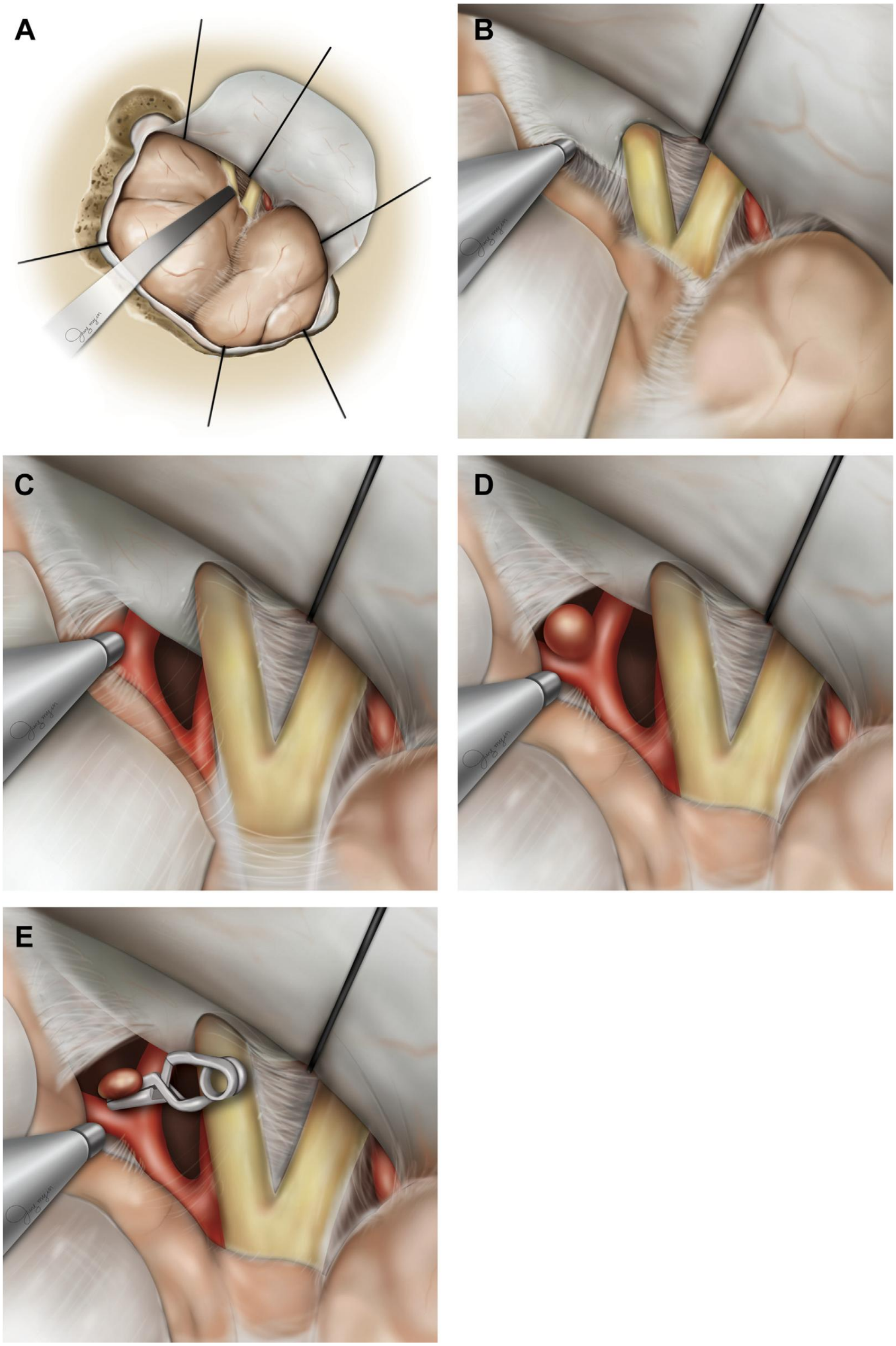

A
B
C
D
E

Figure 2. In a 63-year-old woman, preoperative angiography revealed bilateral MCA bifurcation aneurysms.

The length of the contralateral M1 was 19 mm, A) right MCA bifurcation aneurysm, B) left MCA bifurcation aneurysm. C) Preoperative brain CT angiography. Bilateral MCA aneurysms were treated by a right-sided unilateral approach. D), E) Angiography performed 1 week after surgery showing complete surgical clipping of the ipsilateral MCA aneurysm. The contralateral MCA aneurysm had a minimal residual neck. F) Follow-up brain CT angiography after 30 months revealed no regrowth of the residual neck. CT: computed tomography; MCA: middle cerebral artery.

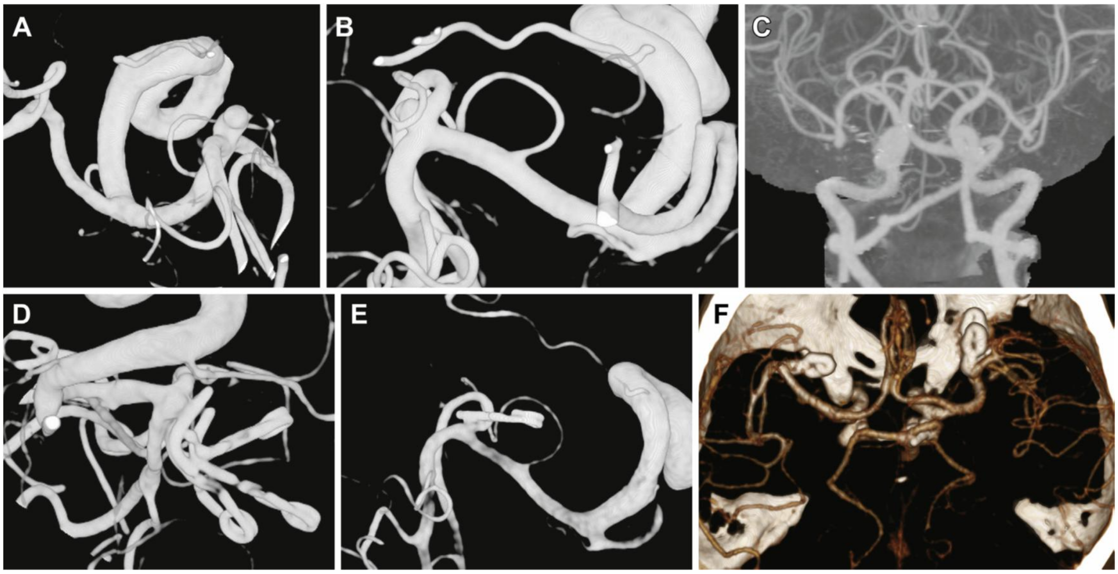


Figure 3. A), B), C) Bilateral mini-craniotomy D) After mini-craniotomy, the dura was opened in a C shape.

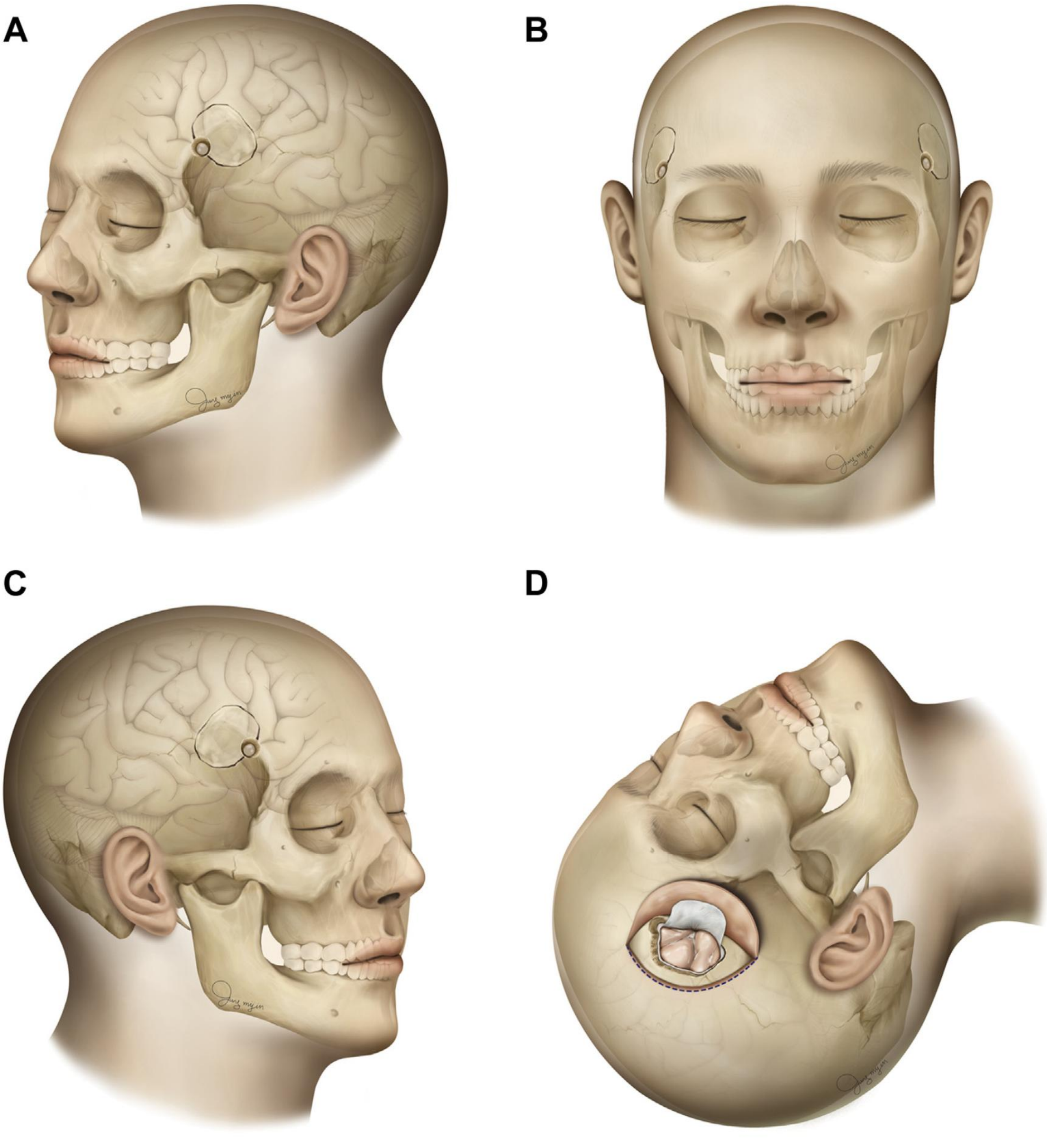
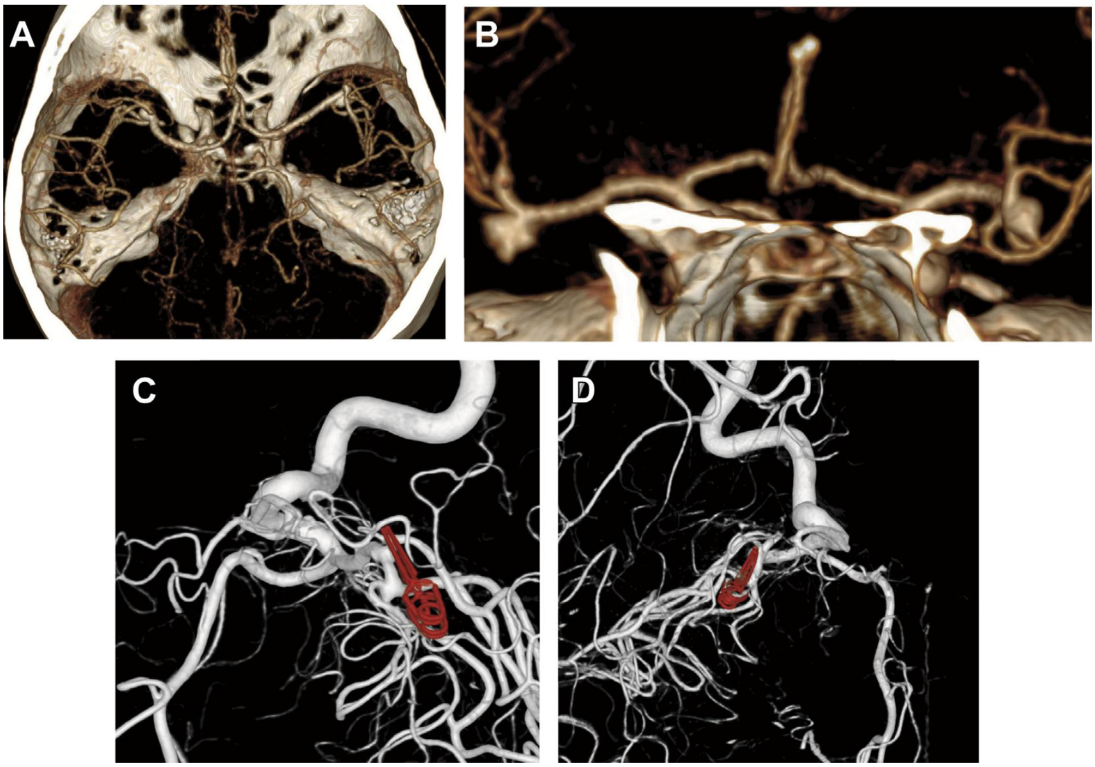


Figure 4. In a 57-year-old woman, preoperative brain CT angiographs revealing bilateral MCA bifurcation aneurysms

Preoperative brain CT angiography A): axial image, B) coronal image. C), D) Bilateral MCA aneurysms treated using a bilateral approach. No residual necks were detected on either aneurysm at 1 week postoperatively in angiography. CT: computed tomography; MCA: middle cerebral artery.



국문 초록

양측성 중대뇌동맥 동맥류 결찰술의 단측 개두술과 양측 개두술의 비교 연구

목적: 이 연구의 목적은 단일 기관에서 비파열성 양측성 중대뇌동맥류에 대해 단일 개두술과, 양측 개두술에 대한 수술 결과 비교 및 그 결과에 영향을 미치는 해부학적, 임상학적 인자에 대해 평가하고자 한다.

대상과 방법: 분당 서울대 병원에서 2011년에서 2014년 사이 양측성 중대뇌동맥 동맥류로 클립 결찰술 받은 환자 데이터를 수집하였고, 19명의 단측 개두술과 10명의 양측 개두술로 환자군을 나눈 뒤 수술법에 따라, 기본적 특성과 임상적,

영상학적 결과 및 나쁜 임상 결과에 영향을 주는 위험 인자에 대해 후향적으로 분석을 시행하였다.

결과: 동맥류의 특성들과 영상학적 인자들은 두 수술간의 수술 결과에 통계적으로 유의한 관련을 보이지 않았다. 단측 개두술을 받은 군의 환자들(11/19, 58%)은 수술 후 후각신경 기능저하 발생률이 높았으며, (10/19, 53%)의 환자들에서 반대쪽 중대뇌동맥류에 동맥류 일부가 남는 경우가 많았다. 수술 후 후각 신경 저하 발생에 관해서는 두 군간에 유의미한 차이가 있었다 (P = 0.003). 양측 개두술을 받은 군의 환자들은 수술 후 후각신경 기능저하 및 반대쪽 중대뇌동맥류에 동맥류가 남는 경우가 없었으며, 모든 환자가 수정랜킨수치 0 점으로 좋은 임상적 결과를 보였다.

결론: 양측성 중대뇌 동맥의 동맥류에 대한 양측성 개두술은 단측성 개두술에 비해 합병증이 적었고, 더 나은 수술적 결과를 보여주었다. 양측성 개두술은 반대쪽 중대뇌동맥의 동맥류를 완벽하게 결찰 하는데 있어서 전두엽을 많이 당길 필요가 없으므로, 수술 후 후각신경 기능 저하가 발생하지 않았다. 그러므로, 양측성 개두술은 양측성 중대뇌 동맥의 동맥류를 치료하는데 있어서 안전하고 효과적인 치료법으로 사료된다.

....

주요어: 양측성 개두술, 양측성 중대뇌 동맥 동맥류, 수술 후 후각 기능저하, 단측성 개두술

학 번: 2016-21944