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Original Article

Modified Supraorbital Keyhole Approach to Anterior Circulation Aneurysms

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Objective : To select a surgical approach for aneurysm clipping by comparing 2 approaches.

Materials and Methods : 204 patients diagnosed with subarachnoid hemorrhage treated by the same neurosurgeon at a single institution from November 2011 to October 2013, 109 underwent surgical clipping. Among these, 40 patients with Hunt and Hess or Fisher grades 2 or lower were selected. Patients were assigned to Group 1 (supraorbital keyhole approach) or Group 2 (modified supraorbital approach). The prognosis according to the difference between the two surgical approaches was retrospectively compared.

Results : Supraorbital keyhole approach (Group 1) was performed in 20 aneurysms (50%) and modified supraorbital approach (Group 2) was used in 20 aneurysms. Baseline characteristics of patients did not differ significantly between two groups. Total operative time (p = 0.226), early ambulation time (p = 0.755), length of hospital stay (p = 0.784), Glasgow Coma Scale at discharge (p = 0.325), and Glasgow Outcome Scale scores (p = 0.427) did not show statistically significant differences. The amount of intraoperative hemorrhage was significantly lower in the supraorbital keyhole approach ($p < 0.05$).

Conclusion : The present series demonstrates the safety and feasibility of the two minimal invasive surgical techniques for clipping the intracranial aneurysms. The modified supraorbital keyhole approach was associated with more hemorrhage than the previous supraorbital keyhole approach, but did not exhibit differences in clinical results, and provided a better surgical view and convenience for surgeons in patients with Hunt and Hess or Fisher grades 2 or lower.

Keywords Minimally invasive surgical procedures, Craniotomy, Intracranial aneurysm

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INTRODUCTION

Among the intracranial aneurysm surgical clipping approaches that have been developed, the most accepted is the pterional approach described by Yasargil and Fox.[21] However, the conventional pterional approach has potential side effects, such as excessive hemorrhage, pain, muscular atrophy caused by the severing and exfoliating the temporalis muscle, asymmetrical facial shape, and damage to the stem of the facial muscles.[7,15] The some types of supraorbital approach was developed as an alternative to the pterional approach because of these side effects, and led to the introduction of the transciliary supraorbital keyhole approach, both of which are widely used today.[2,4,13,16,20] However, supraorbital keyhole approaches have drawbacks, including limitation of the surgical view and space, and the risk of damage to the frontalis branch of the facial nerve.[6,11]

Accordingly, this study aimed to retrospectively compare the clinical results in patients who underwent the two supraorbital approaches (supraorbital keyhole approach vs. modified supraorbital approach).

MATERIALS AND METHODS

Patients

A total of 204 patients were diagnosed with subarachnoid hemorrhage caused by a ruptured intracranial aneurysm in a single medical center between November 2011 and October 2013. Among these, 109 cases underwent clipping by the same neurosurgeon. The conventional supraorbital keyhole approach were allocated to Group 1, and those who underwent the modified supraorbital approach were allocated to Group 2. We set the inclusion criteria for subarachnoid hemorrhage patients to select those with Hunt and Hess and Fisher grades 2 or lower in order to create similar preoperative clinical conditions. Patients with a previous history of an intracranial lesion were excluded. Finally, 40 aneurysms were included in the study.

The clinical results evaluated included total operative time, extent of intraoperative hemorrhage, early ambulation time, duration of hospital stay, and discharge Glasgow Outcome Scale (GOS) score. Total operative time was defined as the time from the start to end of general anesthesia. To assess the extent of intraoperative hemorrhage, we used the following values: estimated blood loss (EBL), pre and post-operative hematocrit (Hct) change, and transfusion volume.

Operative technique

In Group 1 (supraorbital keyhole approach), the skin incision was started medial to the supraorbital notch and beyond the tail of the eyebrow. A small keyhole was made at the frontozygomatic suture, and an approximate 2 × 2-cm craniotomy was performed (Fig. 1A).

In Group 2 (modified supraorbital keyhole approach), with a conventional pterional skin incision and inter-fascial dissection, the superolateral orbital rim was exposed. A minimal dissection of the temporalis muscle was performed from the anterior aspect of the supratemporal ridge. A keyhole was made about 0.5 cm down the frontozygomatic suture. An approximate 3 × 3-cm frontotemporal craniotomy was

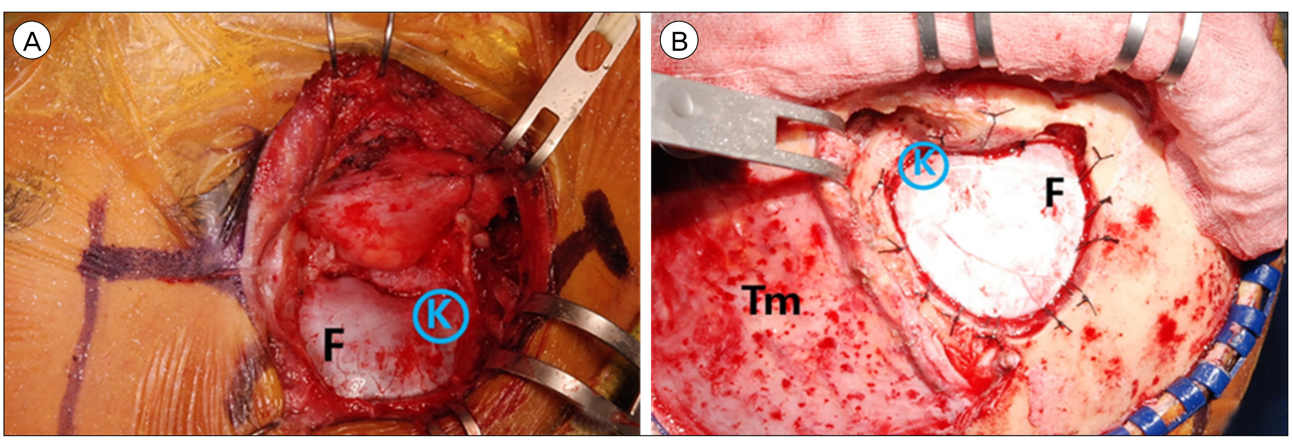

Fig. 1. Surgical methods to the anterior circulation aneurysm clipping. (A) Group 1 (Supraorbital keyhole approach), (B) Group 2 (Modified supraorbital keyhole approach). Tm = temporalis muscle; F = frontal lobe; K = key hole.

Table 1. Clinical characteristics of the patients

		Group 1	Group 2	Total	*p* value
Age	Mean ± SD	57.10 ± 11.17	57.60 ± 15.12	57.35 ± 13.12	0.906
	≤ 49	5 (25.0)	6 (30.0)	11 (27.5)	0.924
	50-59	7 (35.0)	7 (35.0)	14 (35.0)	
	≥ 60	8 (40.0)	7 (35.0)	15 (37.5)	
Sex	Male	10 (50.0)	10 (50.0)	20 (50.0)	1.000
	Female	10 (50.0)	10 (50.0)	20 (50.0)	
Total		20 (100.0)	20 (100.0)	40 (100.0)	

Values are presented as mean ± SD or n (%).
SD = standard deviation

made, including a part of the superior orbital wall (Fig. 1B).

After the craniotomy was completed, the operative technique did not differ between the groups. The dura was opened in semicircular fashion over the Sylvian fissure. If the brain was tight despite mannitol, cerebrospinal fluid was removed by intraoperative ventriculostomy at Paine's point or a modified Paine's point.[12)14)] Arachnoid fissure dissection was generally performed laterally to medially, but occasionally medially to laterally. Whenever possible, veins of the Sylvian fissure and sphenoparietal sinus were preserved to minimize venous congestion. We performed complete proximal artery control to enable a prompt response to intraoperative aneurysm rupture, and carefully dissected arterioles around the neck of the ruptured aneurysm. When there was atherosclerotic change of the neck of the aneurysm, we slightly adjusted the location of the clip.

Data analysis

All analyses were performed using SPSS ver. 19.0 for Windows (SPSS Inc., Chicago, IL, USA). Results are presented as mean ± standard deviation (SD). Student's *t*-test or the chi-square test was used to identify differences between the groups. A *p*-value of <0.05 was considered significant.

RESULTS

The mean age of the study subjects was 57.35, and there were 10 males and 10 females in each group. There were no statistically significant differences in sex and age between the two groups (Table 1). The Hunter Hess grade (1.50 ± 0.61 vs. 1.50 ± 0.61, p = 0.780) and Fisher grade (1.65 ± 0.49 vs. 1.40 ± 0.50, *p* = 0.119) also did not show statistically significant differences between the two groups. The mean operative time was 5.34 ± 1.11 h in Group 1, and 5.75 ± 1.02 h in Group 2 (p = 0.226).

EBL, Hct change, and total amount of blood transfused showed statistically significant differences between groups ($p < 0.05$). In particular, the values were lower in the supraorbital group than in the modified supraorbital approach (Table 2). EBL was 192.00 ± 33.02 mL in Group 1 and 632.50 ± 86.26 mL in Group 2 ($p < 0.05$). Pre- and postoperative Hct change was 4.15 ± 1.73 in Group 1 and 8.70 ± 1.38 in Group 2 ($p < 0.05$). The total amount of blood transfused was 125.00 ± 151.74 mL in Group 1 and 500.00 ± 114.71 mL in Group 2 ($p < 0.05$).

Early ambulation time, length of hospital stay did not show statistically significant differences. Early ambulation time was 9.30 ± 2.87 days in Group 1 and 9.00 ± 3.16 days in Group 2 (p = 0.755), and total hospital stay was 18.20 ± 7.05 days in Group 1 and 17.65 ± 5.45 days in Group 2 (p = 0.784).

No statistical differences were observed in Admission Glasgow Coma Scale (GCS) score (p = 0.752) and Discharge GOS (p = 0.427).

In group 1, postoperative complications included death (due to acute respiratory distress syndrome

Table 2. Comparison of clinical results different surgical approaches to the cerebral aneurysm clipping

	Group 1	Group 2	*p* value
Hunt-Hess grade	1.50 ± 0.61	1.45 ± 0.51	0.780
Fisher grade	1.65 ± 0.49	1.40 ± 0.50	0.119
Operation time (hour)	5.34 ± 1.11	5.75 ± 1.02	0.226
EBL (mL)	192.00 ± 33.02	632.50 ± 86.26	0.000*
Hct change	4.15 ± 1.73	8.70 ± 1.38	0.000*
Total transfusion volume	125.00 ± 151.74	500.00 ± 114.71	0.000*
Early ambulation time (day)	9.30 ± 2.87	9.00 ± 3.16	0.755
Hospital stay (day)	18.20 ± 7.05	17.65 ± 5.45	0.784
Admission GCS	14.60 ± 0.50	14.65 ± 0.49	0.752
Discharge GCS	14.05 ± 2.65	14.65 ± 0.49	0.325
Discharge GOS	4.40 ± 0.94	4.60 ± 0.60	0.427

Values are presented as mean ± SD.
EBL = estimated blood loss; Hct = hematocrit; GCS = Glasgow coma scale; GOS = Glasgow outcome scale

caused by postoperative pneumonia in 1), symptomatic vasospasm (1 patient), and cerebral artery infarction (1 patient). In Group 2, 2 patients had symptomatic vasospasm, and 1 had a frontal sinus opening.

Patients of Group 1 were satisfied with their appearance, and were happy to have avoided a head shave. However, 2 patients had postoperative frontal muscle weakness and numbness. Those complications were completely resolved within six months. In Group 2, there were no symptoms of facial nerve palsy. Both groups had no complications for surgical wounds, including orbital swelling, depression of the operated site.

DISCUSSION

The pterional approach for aneurysm clipping, which was first described by Yasargil and Fox,[21] is a familiar surgical method that is widely used because of its primary advantage of better surgical view, clear anatomic exposure of most of the arteries (including the posterior communicating artery), and many other benefits. However, the pterional approach also has some disadvantages, such as possible muscle atrophy or pain after the exfoliation of the temporal region, and cosmetic dissatisfaction due to surgical scarring.[7)15)] Hence, the need for a surgical method that provides the same clear anatomic exposure led many neurosurgeons to design various successful and minimally-invasive surgical approaches.

In 1971, Wilson and colleagues were able to operate on intracranial lesions through a minimal craniotomy site.[19)] Studies revealed that these less invasive surgical methods resulted in less tissue damage and decreased cerebral edema compared with existing surgical methods. In 1978, Brock used the method of frontotemporal craniotomy for anterior circulation aneurysm clipping, in which the resulting surgical wound was only 3-5 cm in diameter.[3)] In 1982, Jane described the supraorbital craniotomy, which opened the anterior orbital roof, thus minimizing traction and exposure of the cranial structures, and decreasing complications that would have arisen with a different approach.[10)] Paladino and colleagues introduced the concept of the keyhole approach, and opened a new chapter in the field of minimally-invasive neurosurgery; however, those authors were faced with the shortcomings of the technique, including the limitation of surgical view.[13)] In 1998, van Lindert and colleagues introduced the supraorbital keyhole approach,[18)] while Paladino announced the transciliary keyhole approach.[13)] Many other studies described surgical methods with more advantages than those with the pterional approach, including less invasiveness, shorter operative time, and the ability to control the size of the craniotomy.

However, these minimally-invasive surgical methods could not be applied to all patients. First, the supraorbital keyhole approach itself does not actually decrease the danger of the operation, which demands a skilled surgeon who can operate in a narrow space.[20]

In addition, the exposure of the frontal sinus in cases of supraorbital craniotomy performed on patients with a large sinus increases the possibility of an infection, causing surgical limitations. Van Lindert and colleagues performed a supraorbital craniotomy for aneurysm clipping in 139 patients. The average craniotomy size was 2-3.5 cm in width and 1.5-2 cm in height. They reported no frontal sinus exposure and emphasized the importance of measurement of the frontal sinus by imaging of the lesions prior to the operation.[18] In our research, aneurysm clipping using the transciliary supraorbital keyhole approach led to frontal sinus exposure in 1 of 10 patients. This patient's frontal sinus was approximately 4.5 cm wide, measured from the center of the face.

Moreover, surgeons must avoid damaging the supraorbital nerve during the transciliary supraorbital keyhole approach. In 2010, Trivedi and colleagues carried out a study of the cranial supraorbital notch and supraorbital foramen in 249 patients.[17] Their results showed that the supraorbital notch was on average 24.30 mm from the center of the cranium, whereas the left side showed a mean distance of 23.73 mm and did not exceed 31.68 mm. Therefore, it was concluded that neurological damage might occur if the craniotomy is performed 4 cm away from the center of the cranium (considering the size of the frontal sinus) during the transciliary supraorbital keyhole approach.

The supraorbital keyhole approach provided an unfamiliar view to the surgeon compared to the conventional pterional approach. The sylvian fissure presents in the lateral side of surgical window in the supraorbital keyhole approach. It is difficult to approach

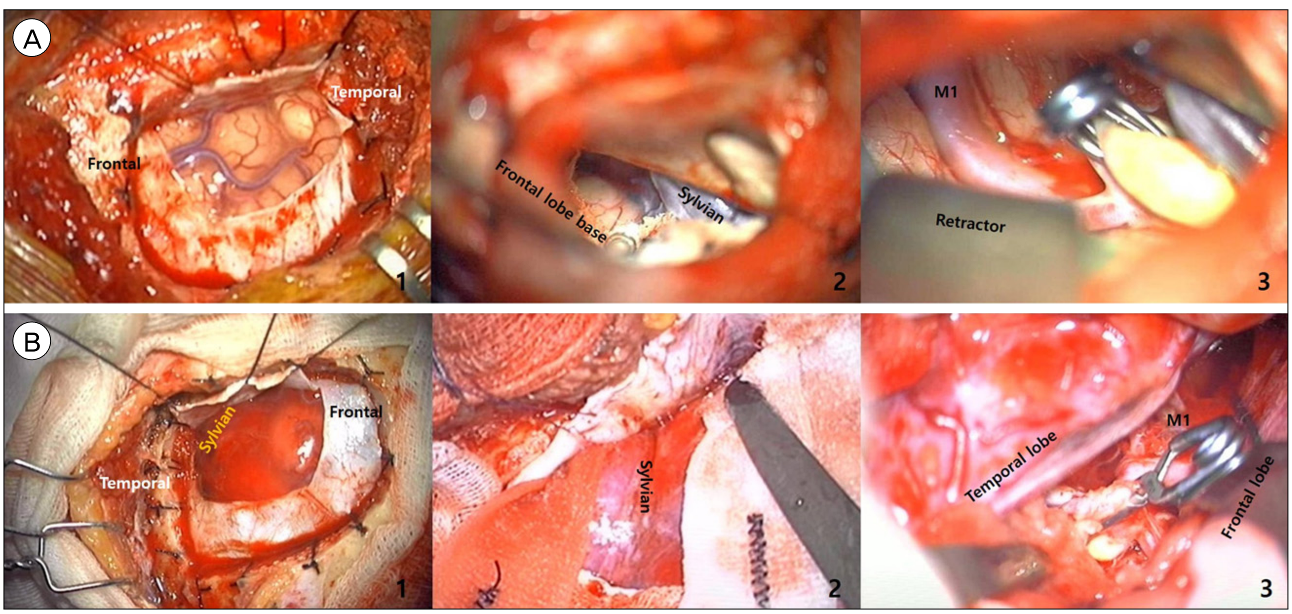

Fig. 2. Microscope view (A) Group 1 (Supraorbital keyhole approach). Clipping of ruptured aneurysm of Rt. MCA bifurcation. Operative view under craniotomy and durotomy. The sylvian vein is not well exposed as it is hidden under the lateral side of the craniotomy site (A-1). Approaching the Sylvian vein using a subfrontal approach (A-2). The retractor is placed under the frontal base. The angle of the retractor is nearly perpendicular to the skull base (A-3). (B) Group 2 (Modified supraorbital keyhole approach). Clipping of ruptured aneurysm of Lt. MCA bifurcation. The path of the Sylvian vein is well exposed after durotomy (B-1). The frontal lobe and temporal lobe is retracted to the side and allows for a more accessible Sylvian dissection (B-2). The retractor angle is less steep and the angle between retractors is wider (B-3). MCA = middle cerebral artery.

the sylvian fissure and the viewing angle along with the microscopic lighting is limited. Therefore, much more skill and thorough knowledge of the surgical anatomy is required for the keyhole approach. The narrow intraoperative viewing angle and limitation of microscope lighting could be overcome by the application of endoscopes to obtain details in close-up fields.[5] We did not apply the use an endoscope in any of our cases.

Although the size of bone flap was not different between the two groups, modified supraorbital keyhole approach provided more familiar view as in the conventional pterional approach. The modified supraorbital keyhole approach allowed for a convenient to approach to the sylvian fissure and required less brain traction in dissection of the aneurysm (Fig. 2).

In addition, use of two suction tubes is challenging in surgery on a ruptured aneurysm due to the narrow view, and proximal control can be difficult. Some researchers advocated additional osteotomy because of the operational limitations of a prominent orbital rim limiting access to the skull base.[1)8)11)16)] In order to overcome this limitation of the supraorbital keyhole approach, this study modified the traditional approach and performed a posterior hairline incision, immediately removing a part of the superior orbital rim in the craniotomy.

As the incision enlarged, the amount of intraoperative hemorrhage and the need for postoperative transfusion increased. However, there was no significant change in hospital stay and prognosis of patients due to the increased hemorrhage in our two subgroups. Better surgical view and space could be obtained, and conversion to expanded craniectomy could be performed in cases where intracranial pressure suddenly increased during the operation, with accompanying cerebral edema.

In our study, the subjects were compared to patients with Hunt and Hess or Fisher grade 2 or lower, with little brain damage, or low intracranial pressure (ICP). However, there are more patients with high ICP due to cerebral edema and hematoma in clinical practice settings, and there are many cases with increased ICP for various reasons after surgery.

Güresir and colleagues stressed the importance of deciding on and implementing primary or secondary decompressive craniectomy to the treatment and prognosis of a patient with subarachnoid hemorrhage with a serious increase in ICP, regardless of the patient's pathological physiology (hemorrhage, infarction, or cerebral edema) and condition.[9)] As shown in the current study, when there is need of postoperative secondary craniectomy and an easy means of managing a sudden increase in ICP while performing a posterior hairline incision, rapid surgical treatment can be performed through wound revision rather than through a new incision.

CONCLUSION

Compared two minimal invasive surgery methods of anterior circulation aneurysm treatment. The supraorbital keyhole approach has many merits but also drawbacks compared to the traditional approach. In order to overcome this, the modified supraorbital keyhole approach was performed in this study. The modified supraorbital keyhole approach had more hemorrhage compared to the supraorbital keyhole approach, but there was no difference in clinical results. In addition, the modified supraorbital keyhole approach allows additional treatment to be more readily performed in cases where secondary decompressive craniectomy is needed because of increased ICP.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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