Analysis Surgical Outcomes of Ruptured Anterior Communicating Artery Aneurysm: Lateral Supraorbital Versus Pterional Approach.

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Abstract
Objective To compare lateral supraorbital approach with pterional approach to determine the most effective routine to clip anterior communicating artery aneurysm.

Method A total of 85 patients with anterior communicating artery aneurysm underwent surgical clipping, 34 through the lateral supraorbital approach and 51 through the pterional approach from June 2016 to June 2018 in the department of neurosurgery, Jinhua central hospital. We retrospectively analyzed the demographic and clinical variables including age, sex and Hunt-Hess grade. Accordingly, operative data, clinical outcome and postoperative complications were analyzed. The mRS at discharge and 6 months later were evaluated.

Outcome All aneurysms were completely clipped. There was no significant difference in intraoperative aneurysm rupture rate and intensive care time between the two groups (P>0.05). Compared with the pterional approach, the operation time of the lateral approach was shorter, the amount of bleeding was less, and the bone flap was small, and there was a statistical difference (P<0.05). There was no statistically significant difference in complications between the two groups (P <0.05). There was no significant difference in mRS between the two groups at different time points (P>0.05). There was no significant difference in hospital stay between the two groups (P>0.05).

Conclusion According to our results, we recommend the lateral supraorbital approach for ACoAA and A1/A2 to neurosurgeons who have gained sufficient experience due to its advantages over the pterional approach.

Introduction
Intracranial aneurysm represents one of the most significant cause of subarachnoid hemorrhage, leading to high rate of morbidity and mortality, among which, above 30% comes to anterior communicating artery aneurysm and A1/A2 aneurysms. Many different conventional approaches such as the pterional approaches are used to access anterior circulation aneurysms. These approaches provide brilliant exposure to the anterior and middle cranial fossa. The main limitation of these approaches is that an extended opening is needed to expose the brain. In recent decades, the development of surgical instruments and microsurgical skills has made it possible for most of
neurosurgeons through relatively moderate and specific approaches to treat these lesions. One of these new approaches, supraorbital craniotomy, has been reported to offer a minimally invasive approach to a variety of lesions. Several studies have been reported, but most of these studies included a heterogeneous population of aneurysms (ruptured vs. unruptured and anterior vs. posterior circulation) or lacked a control pterional group. Recently, this approach has been widely applied to the treatment of anterior circulation aneurysms.  

Method

**Patient Population**

At Jinhua Central Hospital, we performed surgery on 81 cases of AComA and A1/A2 aneurysms. All the patients were provided written informed consent for inclusion in the present study before the procedure. The patients underwent microsurgical clipping between January 1, 2016 and July 1, 2018, 34 patients through supraorbital clipping of the aneurysms, and 51 patients via pterional approach. Pterional clipping was chosen more in that study because the pterional approach was used in more cases in Jinhua Central Hospital in the past; the supraorbital technique has only been performed in the past few years. The data were collected retrospectively from patients admitted to the elective or emergency list for aneurysm clipping. The data were collected retrospectively from patients admitted to the elective or emergency list for aneurysm clipping. The data were collected from the patients’ medical records, patient interviews, and by performing computed tomography (CT) angiograms on the patients; the size of the residual aneurysm was also calculated with CT angiograms.

**Inclusion Criteria**

We include 1) symptom and CT scan confirmed spontaneous subarachnoid hemorrhage; 2) CT angiography (CTA) or whole brain Digital Subtraction Angiography (DSA) confirmed anterior communication aneurysm; 3) Hunt-Hess grade I-III; 4) Lateral Supraorbital approach (LSO) or Pterional approach (PA) surgery was taken within 72 hours after admission. We excluded 1) patients with vascular malformations, including arteriovenous malformation and moyamoya disease; 2) patients who had other intracranial aneurysms that were clipped with the MCA aneurysms in the same surgery; and 3) patients with incomplete imaging and clinical data from admission to discharge.
Patients with the following conditions were not considered candidates for keyhole craniotomy: large aneurysms, and aneurysms that required trapping, clipping with an external-internal carotid bypass, or skull base techniques such as large hematomas requiring extensive decompression.

All of the surgeries were performed by the same operators. Pterional clipping was chosen more in that study because the pterional approach was used in more cases in Jinhua Central Hospital in the past; the supraorbital technique has only been performed in the past few years. We reviewed our consecutively collected patients with diagnosed aneurysms between June 2016 and June 2018.

**Surgical Technique**

The patient is placed supine. The head is fixated after being turned about 20 degrees towards the opposite side of the lesion, positioned above the heart level. These steps provide enough perspective to see the base of the skull, as well as to reduce the cranial blood flow and venous congestion. The skin incision begins just above the zygomatic arch, and moves to the frontal area and upwards from half a centimeter behind the hairline. The skin and subcutaneous flap are separated and opened up to the supraorbital region. The anterior branch of the facial nerve is present here and is important for eyebrow movements. Superior temporal line is considered the boundary and the temporal muscle is cut lateral to this line so as to leave 1 cm of muscle on superior temporal line. Then, a single burr hole (MacCarty burr hole) is opened right behind the zygomatic process of the frontal bone. The optic cistern is opened with frontal retraction at the level of the sphenoid small wing. After the carotid cistern is opened, the Sylvian cistern is opened about 3 cm from the proximal to the distal. The A1 separation is seen by following the internal carotid artery after this dissection. Therefore, it is possible to see the opposite sylvian fissure with this opening if the dissection is towards the anterior cerebral artery. However, the direction of the drill while the hole is opened should be towards the posterior and superior as it will enter the orbit otherwise.

Standard PA was performed according to the Yasargil’techniques.

**Observation follow-up**

We recorded surgery related indicators: bone flap size, operation time, amount of bleeding, and
intraoperative aneurysm rupture. At the same time, we observe and compare post-operative complications at 6 months after surgery such as muscle weakness, frontal numbness, hyposmia, scalp incision infection, intracranial infection, hydrocephalus, meningitis, hematoma, cerebrospinal fluid (CSF) leak, postoperative infarct and atrophy of diaphragmatic.

Statistical Analysis
The incidence percentages and 95% confidence intervals (CIs) were calculated for all included variables and outcomes. The quantitative variables are presented as the mean standard deviation and were compared using the Student t test. The Fisher exact 2-sided test was used to compare the categorical variables with the outcome. Statistical significance was set at P < 0.05.

Results
There was no significant difference (P>0.05) in baseline demographic and clinical data. As shown in table 1.
All aneurysms were completely clipped. There was no significant difference in intraoperative aneurysm rupture rate and intensive care time between the two groups (P>0.05). Compared with the pterional approach, the operation time of the upper lateral approach was shorter, the amount of bleeding was less, and the bone flap was small, and there was a statistical difference (P<0.05), which is likely due to the smaller craniotomy and the faster removal of the smaller supraorbital bone flap. Mean operation time for the pterional approach was 166 min, and the mean operation time for the supraorbital approach was 151 min. There was a statistically significant difference in operation times between the two groups (P = 0.020). The mean blood loss for the pterional approach was 363 ml, and the mean blood loss for the supraorbital approach was 272 ml. There was no statistically significant difference in the amount of blood loss between the two groups (P = 0.172). There was no statistically significant difference in intensive care unit (ICU) stay between the two groups (P = 0.692). We recorded post-operative complications at 6 months after surgery such as muscle weakness, frontal numbness, hyposmia, wound infection, meningitis, cerebrospinal fluid (CSF) leak from the wound and
postoperative infarct. There was no statistically significant difference in complications between the two groups (P = 0.007). Fortunately, in this study, there was no patient who suffered from paresis of the eyebrow. There was 14% of supraorbital patients and 16% of pterional patients that developed meningitis. As shown in table 2.

There was no significant difference in mRS between the two groups at different time points (P>0.05). There was no significant difference in hospital stay between the two groups (P>0.05), as shown in Table 3.

Discussion

The history of intracranial surgery for aneurysms is not long. The pterional approach was first described by Yasargil and Fox in 1974. Since then, this technique has replaced bifrontal and frontolateral craniotomies for access to anterior circulation aneurysms. Conventional large frontotemporal craniotomy uses multiple burr holes and needs to remove of the temporal squama. Patients sometimes complain of a limited ability to open the mouth and pain during chewing resulted from temporal muscle resection and contracture after a conventional frontotemporal craniotomy.

The standard pterional approach requires a large exposure of the brain, which may cause an increase in procedural morbidity not related to the primary lesion. The most common cosmetic impairments after pterional craniotomy was the presence of depressed deformities in the frontotemporal area which result from large skin incision scar, depression of the bone flap, or temporal muscle atrophy.

With the fully understanding that keyhole surgery is not the miniaturization of any standard technique but rather the natural evolution into a more precise and modified procedure, various modified pterional approaches to skull-base lesions have been reported. Recently, Qing Lan et al. documented a large series of 356 aneurysms clipped through supraorbital or pterional approach. A comparison analysis was performed that reported no significant difference in the GOS score, incidence of adverse events, and complete clipping rate between the two groups. Hernesniemi et al. proposed an upper lateral approach through a summary of 2000 operations in the Helsinki Brain Research Center and demonstrated its feasibility as an alternative to the traditional pterional
approach. Figueiredo suggested that the separation of the distal fissure at the distal end does not provide additional exposure to the saddle area, so a mini-sacral approach is proposed, especially for the ACoAA above the optic chiasm, we believe that the exposure of the lateral basal small bone window is sufficient. Salma et al. believe that the superior lateral approach provides an equivalent exposure to the pterional approach for the anterior portion of the arterial ring such as the optic nerve, optic chiasm, and saddle region. Cha et al. believes that the LOS approach can expose the anterior communicating artery and reduce the time and complications of the operation, and the contrast keyhole approach can form a larger bone flap with a more specific perspective angle.

Recently, applying the concept of minimal invasiveness to neurosurgical procedures has gained acceptance among neurosurgeons worldwide. With the trends and innovations in minimally invasive surgery, the LSO is known to result in less approach-related morbidity compared with the classical approaches. Based on our experience, LOS provides a more intuitive perspective that not only allow adequate surgical exposure, but is no less effective than conventional pterional approaches in the treatment of aneurysms. One of the most important aims of the supraorbital keyhole approach is the minimization of brain exposure via limited and more specific craniotomies. Supraorbital craniotomy gives access to the circle of Willis, and dissection of the Sylvian fissure can be performed easily. The lower edge of the skin incision is from the top of the superficial temporal artery, while avoiding the branch of the superficial temporal artery, causing less damage to the superficial temporal artery. Therefore, the post-operative cosmetic results observed in this approach were quite acceptable and even excellent in some cases. However, the direction of the drill while the hole is opened should be towards the posterior and superior as it will enter the orbit otherwise. It is no excessive removal of the sphenoid ridge that reduces the occurrence of cerebrospinal fluid leakage. The burr hole in the frontal bone would be expanded backwards or downwards if additional exposure of the middle cranial fossa is expected. In addition, orbital rim osteotomy provides an intuitive angle of the anterior cranial fossa utilizing natural interval, with even less brain retraction. If the frontal process of the zygomatic bone is removed, the structures of the middle fossa can be well appreciated more easily.
Our results confirmed that the operative time was shorter and the intraoperative blood loss was less in the supraorbital group, which is likely due to the smaller craniotomy and the faster removal of the smaller supraorbital bone flap\textsuperscript{15}. Above all, selective cerebral puncture and drainage to a certain extent can avoid the occurrence and development of hydrocephalus and cerebral vasospasm. In the whole series, one case of cerebral infarction occurred in each of them. After high perfusion and thrombolytic anticoagulant therapy, nerve function was mostly recovered. The incidence of cerebral ischemia was lower, which was significantly lower than that reported \textsuperscript{16}. However, in contrast with notably higher rates of intraoperative aneurysm rupture in the supraorbital group documented by previous studies \textsuperscript{17}, a similar rate of intraoperative aneurysm rupture between the two groups was observed in our study (5.9\% vs. 11.8\%). The supraorbital keyhole approach showed shorter ICU stays and fewer cosmetic disturbances. This retrospective analysis demonstrated that regardless of treatment option, functional outcomes after SAH are dependent upon clinical presentation prior to intervention. In this study, it was shown that there was no statistically significant difference in the mRS outcomes between the supraorbital and pterional groups. Nevertheless, the treatment options for each patient should be individualized based on the clinical presentation, location and available expertise. No matter what the treatment used, patients with poor GOS scores will have poor mRS outcomes at the end of 6 months.

Last but not the least, the supraorbital keyhole approach cannot be adopted as a standard approach. In our study, the patients with a mass effect on the CT scan were regarded as unsuitable for a supraorbital craniotomy. Previous studies \textsuperscript{18} have documented that the supraorbital approach was not suitable for patients with a high Hunt and Hess grade. The study was a single-center, observational registry of consecutive patients who presented with ruptured aneurysm and was reflective of a real-world practice of treatment of poor-grade aneurysms. There is no doubt that the keyhole approach is a more challenging procedure, and it is tough for a surgeon to clip a deep located aneurysm in a narrow corridor. In fact, the surgical techniques required in this approach are associated with a steep learning curve, which somewhat limits its widespread applicability.
Conclusion
The supraorbital keyhole approach appears to be equally effective in the long term for ruptured anterior communicating aneurysms, and this approach should be recommended for neurosurgeons who have gained sufficient experience with the technique due to its advantages over the pterional approach.

Declarations
Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Abbreviations and Acronyms
AComA: Anterior Communicating Artery
CT: Computed Tomography
LSO: Lateral Supraorbital
PA: Pterional Approach
CSF: Cerebrospinal Fluid
CI: Confidence Intervals
ICU: Intensive Care Unit
mRS: modified Rankin Scale
GOS: Glasgow Outcome Scale

Author Contribution Statement
Yu Kaijie: Conceptualization, Methodology, Writing-Original draft preparation. Yurong Cai: Software, Data curation. Zhou Gezhi: Visualization, Investigation. Zhang Jianmin: Supervision. Yuan Jianlie: Software, Validation, Writing- Reviewing and Editing.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Fouding

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Ethics Approval

Not applicable.

Consent for Publication

Not applicable.

Tables

1. Baseline demographic and clinical data and group comparisons after propensity score matching of the patients
| Character                  | Supraorbital | Pterional | $c^2 \& t$ | P   |
|---------------------------|--------------|-----------|------------|-----|
| Female (n)                | 23           | 36        | 0.083      | 0.773 |
| Age (mean ±SD)            | 52.4±10.8    | 53.5±10.1 | 0.332      | 0.742 |
| H-H grade (n)             |              |           | 0.101      | 0.951 |
| I                         | 10           | 1         |            |      |
|                           |              |           | 6          |      |
| II                        | 15           | 23        |            |      |
| III                       | 9            | 12        |            |      |
| Hypertension (n)          | 13           | 22        | 0.202      | 0.653 |
| Diabetes (n)              | 6            | 14        | 1.090      | 0.297 |
| smoking (n)               | 7            | 8         | 0.337      | 0.561 |
| Alcohol (n)               | 7            | 12        | 0.102      | 0.750 |
| Symptoms (n)              |              |           | 2.833      | 0.243 |
| Headache                  | 21           | 40        |            |      |
| Blurred vision            | 9            | 8         |            |      |
| Others                    | 4            | 3         |            |      |

2. Comparison of two surgical approaches in surgical related indicators
|                                | Supraorbital | Pterional | P value |
|--------------------------------|--------------|-----------|---------|
| Operating time (mean minutes)  | 151±31       | 166±26    | 0.020   |
| Intraoperative blood loss (ml) | 272±26       | 303±29    | 0.017   |
| Craniotomy size (cm²)         | 12.9±2.8     | 27.1±4.3  | 0.005   |
| Intraoperative rupture (%)     | 2(5.9)       | 6(11.8)   | 0.363   |
| The stay in ICU (d)            | 2.1±0.8      | 3.2±1.1   | 0.692   |
| Procedural complication (%)    |              |           |         |
| Intracerebral hematoma (%)     | 2            | 2         | 0.676   |
| Ischemic events (%)            | 3            | 2         | 0.347   |
| Intracranial infection (%)     | 2            | 11        | 0.044   |
| Hospital stay (d)              | 15.1±3.6     | 16.4±3.9  | 0.163   |
3. GOS score and length of stay in different groups of patients at different time periods
| GOS | PA   | LOS | P   |
|-----|------|-----|-----|
| discharge |      |     | 0.513* |
| 5   | 22   | 13  |     |
| 4   | 13   | 8   |     |
| 3   | 6    | 6   |     |
| 2   | 8    | 7   |     |
| 1   | 0    | 0   |     |

| six months later |      |     | 0.546* |
| 5   | 27   | 18  |     |
| 4   | 15   | 8   |     |
| 3   | 3    | 5   |     |
| 2   | 3    | 2   |     |
| 1   | 1    | 0   |     |

* GOS 4-5 has a good prognosis, and 1-3 has a poor prognosis. There is no statistically significant difference between the two components.

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**Figures**
Figure 1

a, CT imaging of brain showed subarachnoid hemorrhage; b, intracranial CTA showed anterior communicating aneurysm (arrow); c, modified anterior communicating aneurysm clipping, showing surgical incision and bone flap and ventricle puncture; d, Superior temporal line is considered the boundary and the temporal muscle is cut lateral to this line so as to leave 1 cm of muscle on superior temporal line; e f, the actual burr hole size is about 2.5 * 3cm; g, postoperative intracranial CTA shows satisfactory aneurysm clipping; h, three-dimensional reconstruction of the skull after surgery showed good bone flap reduction and good shape.
Figure 1

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