Microsurgical Experience with Supraorbital Keyhole Operations on Anterior Circulation Aneurysms

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Objective: Conventional pterional approach is a commonly used neurosurgical technique for the treatment of cerebral aneurysms. However, this technique requires more extensive brain exposure than other key hole approaches and is sometimes associated with surgical traumatization or cosmetic problems. The aim of this study was to compare the postoperative outcome between pterional and supraorbital keyhole approaches in the patients with anterior circulation aneurysms.

Methods: The authors reviewed patients with anterior circulation aneurysms who underwent aneurysm clipping via pterional or supraorbital keyhole approach at a single institute over a period of 2 years. Ninety-eight patients harboring 108 aneurysms were included in this study. Various outcomes were recorded, which included clinical grade, cosmetic problems, patients' satisfaction and complications such as chewing discomfort, frontal muscle weakness, hyposmia, infection.

Results: The supraorbital approach exhibited a shorter operation time compared with the pterional approach. Complications such as chewing discomfort occurred less frequently in the supraorbital approach group. Moreover, the cosmetic outcome was significantly better in the supraorbital group than in the pterional group.

Conclusion: The supraorbital keyhole approach reduced intra- and postoperative complications, including chewing discomfort and cosmetic disturbances, compared with the conventional pterional approach.

KEY WORDS: Pterional approach · Supraorbital approach · Aneurysm · Clipping · Cosmetic outcome.

INTRODUCTION

The pterional approach has been used in neurosurgery primarily for the treatment of a wide variety of neurosurgical disorders. In vascular neurosurgery, in particular, pterional craniotomy exploits the advantages of naturally occurring planes and spaces that can be used to expose the base of the brain and the major structures of the circle of Willis, without significant brain retraction. However, this traditional approach requires relatively extensive skin, bone, and brain exposure, possibly causing an increase in iatrogenic complications.

In recent decades, however, the improvement of operating microscopes and refined instrumentation allowed the evolution of microneurosurgical techniques. These techniques and the enormous development of diagnostic facilities permit the treatment of certain intracranial lesions using very small openings. Nowadays, increasing evidence shows that keyhole techniques, if applied properly, are appropriate for the obliteration of intracranial aneurysms. Among the various keyhole procedures, the supraorbital approach is most frequently applied to the treatment of supratentorial aneurysms.

The supraorbital keyhole craniotomy via an eyebrow skin incision is well described by Ferneczky et al. The successful management of supratentorial aneurysms by keyhole supraorbital craniotomy has recently been reported. However, a remarkable controversy remains regarding the choice between the supraorbital keyhole approach and the pterional approach, which is the traditional method for the surgical management of patients with anterior circulation aneurysms. Here, we describe our preliminary experience with the supraor-
bital keyhole approach for the clipping of anterior circulation aneurysms and compare it with the traditional periorbital approach in terms of patient’s subjective outcome assessment.

MATERIALS AND METHODS

Patient population

Between July 2006 and April 2008, we clipped 102 patients harboring 113 intracranial aneurysms of the anterior circulation. Among them, ninety-eight patients harboring 108 aneurysms were enrolled in this study. All operations were performed by the same surgeon at a single institute over a 2-year period. The clinical files and surgical reports of these patients were studied to assess the localization and management of the aneurysms, surgery-related complications, and intraoperative and postoperative problems. The patient’s preoperative condition was assessed according to the Hunt-Hess and the Fisher grading scales. Exact diagnostic imaging was completed before surgery in every case, to provide an accurate definition of the variations in the anatomic and pathological structures. Three-dimensional (3D) angiographic computed tomography (CT) was performed preoperatively in all patients. The surgical approach was decided after the careful survey of the patient’s anatomy of intracranial structures and aneurysm. Inferior direction aneurysms on the anterior communicating artery (ACOM) or middle cerebral artery (MCA) aneurysms with a long M1 were excluded from the supraorbital keyhole approach group. Two groups were analyzed for comparability of demographic and clinical variables, which included age, sex, aneurysm location, Hunt-Hess grade, and Fisher grade. Postoperative complications, outcome, and patient’s satisfaction were recorded six months after surgery. Clinical outcome was assessed using the modified Rankin Scale (mRS) at six months after surgery. Poor outcome was defined as a mRS score of 4-6, which indicates severe disability or death. Scar tenderness and cosmetic satisfaction were evaluated using the patient’s subjective sense as a score between 1 and 5. These descriptions were rated on a 5-cm visual analog scale (VAS), with "none" and "most severe imaginable" (scar tenderness, 1 = no pain, 5 = severe pain; cosmetic satisfaction, 1 = very satisfied, 5 = not satisfied). These values were compared between the periorbital and supraorbital keyhole groups. The significance of observed differences between the variables was assessed by a Student’s t-test and a Mann-Whitney U-test. A p value less than 0.05 was considered significant.

Operative technique

The supraorbital keyhole approach performed in this study was described in detail by Perneckzy et al.\(^{28,30}\). The patient was placed in the supine position. The head was elevated above the level of the heart and turned between 15° and 60° to the contralateral side of the intended incision. The extent of head rotation depended on the location of the lesion. For ipsilateral MCA lesions, 15° of head rotation was used; for lesions of the communicating segment of the internal carotid artery (ICA), 20-30° of head rotation has been found to be sufficient. Surgery of the anterior communicating artery required a rotation of 40-60°. The neck of the patient was slightly retroflexed so that the zygomatic arch was the highest point. This position allows the gravity-related self-retraction of the frontal lobe. After sterilizing the eyebrow region, a standard skin incision was made in the superior edge of the eyebrow or on the forehead crease just above the eyebrow, starting from the midpupillary line and extending laterally to just behind the frontal process of the zygomatic bone. The supraorbital nerve and artery, the frontal branches of the facial nerve, and the superficial temporal artery were always preserved. Subcutaneous dissection was performed from the supraorbital foramen to the frontozygomatic suture. The temporalis fascia was incised a few millimeters before its insertion at the anterior temporal line. The keyhole was exposed via subperiosteal dissection of the temporalis muscle.

A burr hole was drilled on the superior temporal line, just above the frontal base. The craniotomy was performed using a high-speed drill. The medial-inferior edge of the craniotomy went around the level of the frontal base and the lateral edge to the sphenoid wing, at a width of 25-30 mm and a height of 15-25 mm. A large frontal sinus is a relative contraindication to this approach. If the frontal sinus was entered, it was exenterated by stripping and cauterizing its mucosa. The sinus was then covered with a periosteal flap. The dura was opened in a semicircular fashion. A conventional microsurgical technique was used with optimal illumination with a operative microscope. The arachnoid of the carotid cistern, the Sylvian fissure, and suprasellar cisterns were opened for CSF drainage, to create enough room for brain retraction and surgical manipulation. To increase CSF drainage, the membrane of the lamina terminalis was sometimes opened. At the end of the operation, a watertight dural closure was obtained using silk suture and fibrin glue. The temporalis muscle and fascia were sutured to the frontal pericranium. The skin was closed layer by layer.

RESULTS

Nine of the 102 patients had two or more aneurysms.
Four out of nine patients presenting with multiple aneurysms were excluded because of the need for multiple surgical approaches. Among the remaining 98 patients, 54 aneurysms were treated with the pericallosal approach, and 50 patients with 54 aneurysms were treated with the supraorbital keyhole approach. Three patients in the pericallosal group and two patients in the supraorbital keyhole group had two aneurysms that were treated via a single surgical approach. Sixty-seven patients were female, and thirty-one were male. The mean age was 55.7 ± 12.3 years. Pre-operative clinical data were presented (Table 1). The two groups showed a similar distribution of aneurysm location. ACOM was the most common lesion site, followed by the posterior communicating artery (PCOM) and MCA bifurcation. There was no significant difference in clinical grade between the two groups (Table 1).

All of the aneurysms were clipped successfully. The overall outcome was good in both groups (Table 2). The mRS scores showed a similar distribution between the pericallosal and supraorbital groups; however, the operative time was markedly decreased in the supraorbital group (p = 0.02). Several complications were noted postoperatively (Table 3). We recorded these complications at two weeks and six months after surgery. Most complications were resolved six months later. Patients in the pericallosal group suffered complications twice as often as patients in the supraorbital group (85% vs. 42%; p < 0.01). The frequency of complications was high in the pericallosal group in most cases, especially regarding chewing discomfort or problem (65% vs. 10%; p < 0.01 at two weeks postoperatively; 40% vs. 6%; p < 0.01 at six months postoperatively). Although frontal numbness was elevated in the supraorbital group (2% vs. 18%; p < 0.01), this complication was resolved at the six-month follow-up in all cases.

The supraorbital group also showed good results regard-

Table 1. Clinical data of patients

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pericallosal group (number of patients)</th>
<th>Supraorbital group (number of patients)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (F/M)</td>
<td>36/12</td>
<td>31/19</td>
<td></td>
</tr>
<tr>
<td>Age (mean years)</td>
<td>52.4</td>
<td>57.8</td>
<td></td>
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<tr>
<td>Location</td>
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<td></td>
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</tr>
<tr>
<td>ACom</td>
<td>21</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>PoCom</td>
<td>14</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>MCA bif.</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>ICA bif.</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Oph. seg.</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACA</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hunt-Hess grade</td>
<td></td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>0</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>15</td>
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<td>5</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Fisher grade</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>18</td>
<td>17</td>
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<tr>
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<tr>
<td>4</td>
<td>11</td>
<td>10</td>
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</table>

AChA : anterior choroidal artery, ACom : anterior communicating artery, bif. : bifurcation, PoCom : posterior communicating artery, Oph. seg. : ophtalmic segment of internal carotid artery

Table 2. Clinical outcome and operation time

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pericallosal group (number of patients)</th>
<th>Supraorbital group (number of patients)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mRS</td>
<td></td>
<td></td>
<td>0.53</td>
</tr>
<tr>
<td>0</td>
<td>27</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>16</td>
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<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mean Op. time (range)</td>
<td>233 min (140-327 min)</td>
<td>160 min (70-187 min)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 3. Postoperative complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>Two weeks after (number of patients)</th>
<th>Six months after (number of patients)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pericallosal</td>
<td>Supraorbital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pericallosal</td>
<td>Supraorbital</td>
<td></td>
</tr>
<tr>
<td>Chewing discomfort</td>
<td>31 (65%)</td>
<td>5 (10%)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Frontal muscle weakness</td>
<td>2 (4%)</td>
<td>2 (4%)</td>
<td>0.96</td>
</tr>
<tr>
<td>Frontal numbness</td>
<td>1 (2%)</td>
<td>9 (18%)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hypoaemia</td>
<td>2 (4%)</td>
<td>4 (8%)</td>
<td>0.42</td>
</tr>
<tr>
<td>Infection</td>
<td>2 (4%)</td>
<td>1 (2%)</td>
<td>0.53</td>
</tr>
<tr>
<td>CSF leakage</td>
<td>3 (6%)</td>
<td>0 (0%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>41 (85%)</td>
<td>21 (42%)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

CSF : cerebrospinal fluid
ing cosmetic outcome (Table 4). Scar
tenderness was significantly lower in the
supraorbital group (2.1 ± 0.7 vs. 1.7 ± 0.7; p = 0.003). Cosmetic
satisfaction was better in the pretemporal
group, although this result was not significant (p = 0.093).

Illustrative case
Fig. 1 demonstrates a case of supraorbital keyhole
approach. This 72-year-old woman presented with an aneurysm
subarachnoid hemorrhage. Hunt-Hess grade was II, and Fisher grade was III in this patient. Neuroimaging
investigation revealed that she had two aneurysms, one on the
left MCA bifurcation and another on the right ophthalmic segment. Based on CT data demonstrating a slight
preponderance of blood in the left sylvian fissure, it was
thought that the left-sided MCA bifurcation aneurysm was
the cause of the subarachnoid hemorrhage. The ruptured
MCA bifurcation aneurysm was clipped via supraorbital
keyhole approach, and the contralateral ophthalmic
segment aneurysm was clipped via the same corridor. A
neurologically normal outcome was achieved (mRS score = 0). The patient complained of forehead numbness
for about two months, which resolved spontaneously. She had
an excellent cosmetic satisfaction (score = 1) and no scar
tenderness (score = 1).

DISCUSSION
Since Yasargil and Fox33 first described frontotemporal
craniotomy with a perional approach, this technique has
replaced bifrontal and frontolateral craniotomies for access
to aneurysms of the anterior circulation. However, the
standard pretemporal approach requires a semicircular skin
incision using either a musculocutaneous flap or an inter-
fascial dissected temporal muscle flap and a conventional
frontotemporal craniotomy30; this relatively wider exposure of the brain can cause an increase in surgical morbidity not
related to the lesion. Patients sometimes complain of post-
operative cosmetic impairments in the frontotemporal area
resulting from the large skin incision scar, depression of the
bone flap, inappropriate repair of burr holes, or temporal
muscle atrophy.

Recently, the application of the minimally invasive con-
cept to neurosurgical procedures has gained acceptance
among neurosurgeons, with the understanding that keyhole
surgery is not the miniaturization of any standard technique
but rather the natural evolution into a more precise and
refined act. Various modified and combined pretemporal
approaches to skull-base lesions have been reported16-27.

<table>
<thead>
<tr>
<th>Table 4.</th>
<th>Cosmetic outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td>Pretemporal app.</td>
</tr>
<tr>
<td>Scar tenderness (mean ± SD)</td>
<td>2.1 ± 0.7</td>
</tr>
<tr>
<td>Cosmetic satisfaction (mean ± SD)</td>
<td>1.5 ± 0.6</td>
</tr>
</tbody>
</table>

Fig. 1. A: Computed tomography (CT) scan revealing a slight
preponderance of blood in the left sylvian fissure in a 72-year-old female
presented with a subarachnoid hemorrhage. B: CT angiography showing
the presence of two aneurysms, one at the left middle cerebral artery
bifurcation and another at the right ophthalmic segment of the internal
cerebral artery. C: A photograph showing a skin incision marking on a
forehead crease. D: Postoperative 3-dimensional CT image demonstrating
the craniotomy site and the bone flap (small box). E: Postoperative CT
angiography showing the aneurysms clipped via one corridor using the supraorbital approach. F: Photograph of the patient
obtained six months after operation demonstrating a minute scar without
depressed deformity.

Pernecky and colleagues32, 24, 27, 38, 50 advocated the keyhole
concept in neurosurgery and have used supraorbital mini-
craniotomy extensively to treat a variety of lesions. Eyebrow
skin incision and supraorbital keyhole craniotomy were
originally recommended for microsurgery of various cerebral
aneurysms and tumors located in the supra- and parasellar
regions32, 28, 30.

One of the most important goals of the supraorbital
keyhole approach is the minimization of the brain exposure
via limited and more specific craniotomies. Exposure of
brain tissue for several hours during extended craniotomies
always means an injury of the surface by nonphysiological
surroundings, such as room air, irrigation media, and cover
material. The supraorbital keyhole approach offers minimal
brain exposure to air and accidental surgical trauma. Moreover, brain retraction is minimized or absent in this procedure. This significantly decreases approach-related surgical morbidity and shortens hospitalization. In terms of operative time, experienced surgeons need less time to perform the surgery using the perioral craniotomy. However, manipulation of the temporal muscle and performing a relatively larger size of the craniotomy may need more time.

The anatomy of the suprasellar area offers several advantages for keyhole approaches from the anterior. The suprasellar area is bordered by the mesencephalon posteriorly and by the temporal lobes laterally. Therefore, approaches from these sides require retraction of brain tissue. Anteriorly, however, there are several windows into the suprasellar area that do not require brain retraction. Supraorbital craniotomy offers access to the circle of Willis, and dissection of the sylvian fissure can be performed easily. The burr hole in the frontal bone may be expanded backwardly or downwardly, if additional exposure of the middle fossa is desired. In addition, orbital rim osteotomy provides a direct view of the anterior cranial fossa, which includes the sellar and suprasellar regions, 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. This approach allows clipping of aneurysms located in the ipsilateral internal carotid artery, anterior communicating artery, and middle cerebral artery, and even in the contralateral internal carotid artery. According to van Lindert et al., there were no approach-related complications in 139 supraorbital keyhole craniotomies performed for aneurysms of the anterior circulation.

The most common cosmetic problem after perioral craniotomy is the presence of depressed deformities in the frontotemporal area which result from temporal muscle atrophy. Conventional, large frontotemporal craniotomy uses multiple burl holes and needs rostrofaring of the temporal squama. Depression of the bone flap or atrophy of the temporals muscle results in a skin dent in the forehead. Patients sometimes complain of limited ability to open the mouth and pain during chewing resulting from temporal muscle resection, contracture after conventional fronto-temporal craniotomy. Small craniotomy, which is sealed with methyl methacrylate and other bone substitutes, is unlikely to cause cosmetic problems. Preservation of the superficial temporal artery, the frontal branches of the facial nerve, and the supraorbital nerve and artery minimizes the risk of wound healing problems. A short skin incision is later hidden by the eyebrow. Therefore, the postoperative cosmetic results observed in this approach were quite acceptable and, in most patients, were excellent. The length of the surgical procedure and hospitalization were significantly reduced compared with standard techniques.

However, supraorbital keyhole approach cannot be adopted as a standard approach. In our study, the patients with a mass effect on a CT scan were regarded not suitable for a supraorbital craniotomy. As described by Nathal and Gomez-Amador, this approach has some limitations. In some cases of MCA bifurcation aneurysm, the M1 segment is too long, and the direction of the dome is lateral or caudal to the surgical view from this approach. This type of case requires an extensive amount of dissection, and the surgical view with a working space is limited in a very deep plane. In cases of posterior communicating artery segment aneurysm, the angle of vision is more rostral, and visualization of the neck area of the aneurysm is not good, especially if the dome has a caudal direction. In addition, small craniotomy offers a diminished opportunity for a change of plan if unexpected findings occur during surgery. This drawback can be overcome by the use of special keyhole-adapted microinstruments and of a neuroendoscope. However, preoperative diagnostic imaging is of paramount importance in this procedure. Each individual patient should be evaluated for the possibility of proximal control, direction of the aneurysm, and application of the aneurysm clip. Although transient loss of supraorbital sensation and paresis of the eyebrow can occur, this deficit appears to recover during postoperative healing. Fortunately, in this study, there was no case who suffered from paresis of the eyebrow.

CONCLUSION

The careful choice of an adequate, less invasive surgical approach with minimal brain exploration may result in a significant reduction of traumatization to intracranial structures. In our experience, the limited supraorbital keyhole approach provides adequate visualization and safe surgical manipulation of anterior circulation aneurysms as others reported. The supraorbital keyhole approach improved postoperative results and resulted in shorter hospitalization times, as there was a reduction in the risk of complications, which included chewing discomfort, temporal muscle weakness, scarification, and cosmetic disturbances. The supraorbital keyhole approaches, which are based on improvements in diagnostic imaging, advanced surgical instruments, and microsurgical skills, constitute an effective and ideal craniotomy technique.
References