Height of aneurysm neck and estimated extent of brain retraction: powerful predictors of olfactory dysfunction after surgery for unruptured anterior communicating artery aneurysms

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OBJECTIVE The highest incidence of olfactory dysfunction following a pterional approach and its modifications for an intracranial aneurysm has been reported in cases of anterior communicating artery (ACoA) aneurysms. The radiological characteristics of unruptured ACoA aneurysms affecting the extent of retraction of the frontal lobe and olfactory nerve were investigated as risk factors for postoperative olfactory dysfunction.

METHODS A total of 102 patients who underwent a pterional or superciliary keyhole approach to clip an unruptured ACoA aneurysm from 2006 to 2013 were included in this study. Those patients who complained of permanent olfactory dysfunction after their aneurysm surgery, during a postoperative office visit or a telephone interview, were invited to undergo an olfactory test, the Korean version of the Sniffin’ Sticks test. In addition, the angiographic characteristics of ACoA aneurysms, including the maximum diameter, the projecting direction of the aneurysm, and the height of the neck of the aneurysm, were all recorded based on digital subtraction angiography and sagittal brain images reconstructed using CT angiography. Furthermore, the extent of the brain retraction was estimated based on the height of the ACoA aneurysm neck.

RESULTS Eleven patients (10.8%) exhibited objective olfactory dysfunction in the Sniffin’ Sticks test, among whom 9 were anosmic and 2 were hyposmic. Univariate and multivariate analyses revealed that the direction of the ACoA aneurysm, ACoA aneurysm neck height, and estimated extent of brain retraction were statistically significant risk factors for postoperative olfactory dysfunction. Based on a receiver operating characteristic (ROC) analysis, an ACoA aneurysm neck height > 9 mm and estimated brain retraction > 12 mm were chosen as the optimal cutoff values for differentiating anosmic/hyposmic from normosmic patients. The values for the area under the ROC curves were 0.939 and 0.961, respectively.

CONCLUSIONS In cases of unruptured ACoA aneurysm surgery, the height of the aneurysm neck and the estimated extent of brain retraction were both found to be powerful predictors of the occurrence of postoperative olfactory dysfunction.

KEY WORDS anosmia; anterior communicating artery; craniotomy; intracranial aneurysm; treatment outcome; vascular disorders

A pterional approach and its modifications are commonly used for clipping most anterior circulation aneurysms. In such an approach, the frontal lobe and olfactory nerve are both retracted to some degree to access aneurysms located in the circle of Willis. In particular, in cases of an anterior communicating artery (ACoA) aneurysm, a retractor is placed across the olfactory tract, which is damaged primarily by retractor pressure and strain. Thus, olfactory dysfunction following a pterional approach occurs most frequently in cases of ACoA aneu-
Olfactory dysfunction after unruptured ACoA aneurysm surgery and also has a considerable impact on the quality of life. Accordingly, the radiological characteristics of ACoA aneurysms affecting the extent of frontal lobe retraction were investigated as risk factors for the occurrence of olfactory dysfunction to facilitate the identification of high-risk patients.

**Methods**

**Patient Population**

Patients who underwent a pterional or superciliary keyhole approach to clip an unruptured ACoA aneurysm between January 2006 and December 2013 at Kyungpook National University Hospital were eligible for this study. The treatment decision, surgical versus endovascular, was made primarily based on the findings of catheter angiography. Surgical treatment was favored over endovascular treatment for patients with the following findings: 1) difficult navigation of the microcatheter into the aneurysm; 2) very small (< 3 mm) aneurysm; 3) wide-necked aneurysms requiring stent-assisted technology; and 4) aneurysms with an arterial branch incorporated into the sac, as long as the patients had no problems related to comorbidity or hemostasis.

**Surgical Procedure**

The pterional or superciliary keyhole approach was performed in a standard manner. The detailed procedures of the superciliary keyhole approach have been previously reported by the current authors. In 2006 and 2007, all patients (n = 11) with an ACoA aneurysm underwent a pterional approach. From 2008, a superciliary approach was predominantly used in patients with an ACoA aneurysm, whereas a pterional approach was more frequently used in those patients with a superior-directing ACoA aneurysm or multiple concomitant aneurysms.

A left- or right-sided approach was determined according to the side of the dominant A1 segment. After the craniotomy, the brain retractor was placed on a wet cotton strip on the inferior surface of the frontal lobe. The frontal lobe and olfactory nerve were then gently retracted to create sufficient space. For a superciliary approach, the retractor was placed subfrontally from an anterior direction through a supraorbital mini-cranietomy, whereas for a pterional-transsylvian approach, the retractor was placed from a more lateral direction.

With the proximal sylvian fissure, chiasmatic cistern, and interhemispheric fissure dissected, the A1 segment was followed to the ACoA complex. If needed, the gyrus rectus was also resected. However, no additional surgical procedures to preserve the olfactory function, such as olfactory nerve dissection or removal of the orbital wall, were performed in this case series. This study was reviewed and approved by an institutional ethics committee. Informed consent for a surgical procedure and any scientific presentation under anonymity were obtained from the patients.

**Data Collection**

Patients’ medical records were reviewed to obtain relevant clinical information, and all the radiological data in this study were obtained using an electronic picture archiving and communication system. In addition to the patients’ age, sex, a history of subarachnoid hemorrhage (SAH) due to the rupture of a concomitant aneurysm, the applied surgical approach (pterional or superciliary keyhole approach), and postoperative occurrence of olfactory dysfunction, the angiographic characteristics of the ACoA aneurysm, including the maximum diameter and projecting direction of the aneurysm and height of the aneurysm neck, were all recorded based on digital subtraction angiography (DSA) and CT angiography (CTA).

To measure the height of the ACoA aneurysm neck, meaning the vertical distance from the level of the planum sphenoidale to the highest point of the aneurysm neck, sagittal brain images were reconstructed using preoperative (n = 62) and postoperative (n = 60) CTA as the source images. When using postoperative CTA, the height was measured based on the aneurysm dimension and the heights of the A1–A2 junction and aneurysm clip, whereas it was measured directly when using preoperative CTA (Fig. 1). The extent of brain retraction was then estimated based on the measured height of the ACoA aneurysm neck as follows: 1) 3 mm was added to the neck height of a superior-directing ACoA aneurysm; 2) 2 mm was added to the neck height of a superior-directing ACoA aneurysm with

**FIG. 1.** Sagittal brain images reconstructed using CTA source images. The height of the aneurysm neck was measured from the level of the planum sphenoidale in cases of inferior-directing (A), anterior-directing (B), and superior-directing (C) ACoA aneurysms.
a diameter > 5 mm; and 3) 1 mm was added to the neck height of both an inferior-directing ACoA aneurysm and an anterior-directing ACoA aneurysm with a diameter ≤ 5 mm.

**Evaluation of Olfactory Function**

Those patients who complained of permanent olfactory dysfunction after the aneurysm surgery, during a postoperative office visit or telephone interview, were invited to undergo an olfactory test, the Korean version of the Sniffin’ Sticks test. ¹ The process included threshold, discrimination, and identification tests, where each test was scored from 0 to 16. Anosmia, hyposmia, and normosmia were diagnosed with a total score < 15, 15–30, and > 30, respectively. No patient had a preoperative history of olfactory dysfunction.

**Statistical Analysis**

The statistical analyses were performed with the aid of commercially available statistical software (SPSS version 19.0; SPSS, Inc.). Univariate and multivariate analyses were both performed. The following variables were investigated as potential risk factors for postoperative olfactory dysfunction: age, sex, a history of SAH, the surgical approach (pterional vs superciliary), diameter and direction of the ACoA aneurysm, height of the ACoA aneurysm neck, and estimated extent of brain retraction. A 2-sample t-test was used for the quantitative variable (age), while a chi-square analysis was used for the categorical variables. A multivariate analysis was then performed using binary multiple logistic regression. The results were considered significant for p values < 0.05. Meanwhile, a receiver operating characteristic (ROC) analysis was performed to determine the best cutoff value affecting the olfactory function and to compare the predictability of the variables, including the diameter of the ACoA aneurysm, height of the ACoA aneurysm neck, and estimated extent of brain retraction.

**Results**

**Patients**

A total of 102 patients who underwent a pterional or superciliary keyhole approach to clip an unruptured ACoA aneurysm from 2006 to 2013 were included in this study. The baseline data, including the clinical characteristics, surgical approaches, and radiological characteristics of the ACoA aneurysms, are summarized in Table 1. The mean age of the patients was 58.1 years (range 34–76 years), and 42 patients (41.2%) were male. Eighty-eight patients (86.3%) reported subjective olfactory dysfunction after surgery, 11 of whom (10.8%) exhibited objective olfactory dysfunction in the Sniffin’ Sticks test; 9 of these 11 were anosmic and 2 were hyposmic. In the univariate analysis, the diameter and direction of the ACoA aneurysm, height of the ACoA aneurysm neck, and estimated extent of brain retraction were significantly different between the normosmic patients and the anosmic/hyposmic patients. In contrast, no between-group differences were found for age, sex, history of SAH, and surgical approach (pterional vs superciliary; Table 2).

**Multivariate Analysis of Variables for Postoperative Olfactory Dysfunction**

The multivariate analysis with binary multiple logistic regression revealed that the height of the ACoA aneurysm neck, estimated extent of brain retraction, and direction of the ACoA aneurysm were all statistically significant (p < 0.001) risk factors for postoperative olfactory dysfunction (Table 3). The diameter of the ACoA aneurysm was close to being statistically significant (p = 0.059).

**ROC Analysis**

The analysis of the ROC curves showed a discriminatory ability between the normosmic patients and the anosmic/hyposmic patients for the following variables: diameter of the ACoA aneurysm, height of the ACoA aneurysm neck, and estimated extent of brain retraction (Fig.

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**TABLE 1. Clinical and angiographic characteristics of 102 patients who underwent surgical clipping for unruptured ACoA aneurysms**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No. of Patients (%)</th>
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<tbody>
<tr>
<td>Mean age ± SD (yrs)</td>
<td>58.1 ± 9.7</td>
</tr>
<tr>
<td>Male</td>
<td>42 (41.2)</td>
</tr>
<tr>
<td>History of SAH</td>
<td>14 (13.7)</td>
</tr>
<tr>
<td>Incidental ACoA aneurysm</td>
<td>88 (86.3)</td>
</tr>
<tr>
<td>Surgical approach</td>
<td></td>
</tr>
<tr>
<td>Pterional</td>
<td>24 (23.5)</td>
</tr>
<tr>
<td>Superciliary</td>
<td>78 (76.5)</td>
</tr>
<tr>
<td>Mean diameter of ACoA aneurysm ± SD (mm)</td>
<td>5.5 ± 2.6</td>
</tr>
<tr>
<td>Direction of ACoA aneurysm</td>
<td></td>
</tr>
<tr>
<td>Inferior</td>
<td>26 (25.5)</td>
</tr>
<tr>
<td>Anterior</td>
<td>47 (46.1)</td>
</tr>
<tr>
<td>Superior</td>
<td>29 (28.4)</td>
</tr>
<tr>
<td>Mean height of ACoA aneurysm neck ± SD (mm)</td>
<td>7.6 ± 2.6</td>
</tr>
<tr>
<td>Mean estimated extent of brain retraction ± SD (mm)</td>
<td>9.4 ± 2.9</td>
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</tbody>
</table>
Olfactory dysfunction after unruptured ACoA aneurysm surgery

2). An ACoA aneurysm diameter > 5.1 mm, ACoA aneurysm neck height > 9 mm, and estimated brain retraction > 12 mm were chosen as the optimal cutoff values for differentiating anosmic/hyposmic from normosmic patients. The area under the ROC curve (AUC) for the diameter of the ACoA aneurysm was low at 0.788. However, the height of the ACoA aneurysm neck and estimated extent of brain retraction had a significantly higher AUC (0.939 and 0.961, respectively), making them excellent predictors of postoperative olfactory dysfunction.

The sensitivities and specificities of these 3 cutoff values were: 90.9% (95% confidence interval [CI] 58.7–99.8) and 59.3% (95% CI 48.5–69.5) for diameter of the ACoA aneurysm; 100% (95% CI 71.5–100) and 84.6% (95% CI 75.5–91.3) for height of the ACoA aneurysm neck; and 100% (95% CI 71.5–100) and 92.3% (95% CI 84.8–96.9) for estimated extent of brain retraction.

Postoperative Mortality and Morbidity

This case series had no deaths, and only 1 patient experienced permanent postoperative morbidity affecting the Glasgow Outcome Scale score. The patient was a 74-year-old man with a superior-directing, wide-necked ACoA aneurysm and a middle cerebral artery aneurysm, and the neck of the ACoA aneurysm was lacerated during dissection and repaired using a microsuturing technique with a superciliary approach. He developed a brain retraction injury and hydrocephalus postoperatively, and experienced some gait disturbance.

Discussion

Although a pterional approach and its modifications for an ACoA aneurysm are known to present a risk to olfaction, this study is the first attempt to identify effective predictors of the occurrence of postoperative olfactory dysfunction in cases of an unruptured ACoA aneurysm. As a result, the height of the ACoA aneurysm neck and the estimated extent of brain retraction were both found to be powerful predictors.

The extent of brain retraction was estimated to present the minimal extent of frontal lobe retraction for dissection of the aneurysm neck and application of a clip during surgery. For an inferior-directing aneurysm arising from the inferior wall of the A1–A2 junction, at least 1 mm is

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>p Value*</th>
</tr>
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<tbody>
<tr>
<td>Diameter of ACoA aneurysm</td>
<td>1.266</td>
<td>0.991–1.617</td>
<td>0.059</td>
</tr>
<tr>
<td>Direction of ACoA aneurysm</td>
<td>Inferior</td>
<td>0.000</td>
<td>0.000–0.010</td>
</tr>
<tr>
<td></td>
<td>Anterior</td>
<td>0.002</td>
<td>0.000–0.038</td>
</tr>
<tr>
<td></td>
<td>Superior</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Height of ACoA aneurysm neck</td>
<td>24.404</td>
<td>5.117–341.178</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Estimated extent of brain retraction</td>
<td>0.025</td>
<td>0.005–0.135</td>
<td>&lt;0.001</td>
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* Significant differences by multivariate analysis (p < 0.05) are in bolded text.
retracted from the aneurysm neck to dissect along the A1 segment. In cases of an anterior-directing aneurysm with a diameter > 5 mm, dissection of the superior part of the aneurysm neck is considered to require retraction of 2 mm from the aneurysm neck, while 3-mm retraction from the aneurysm neck is required to expose the bilateral aspects of the neck of a superior-directing aneurysm arising from the superior wall of the A1–A2 junction.

Based on results from previous studies of ruptured aneurysms, surgical clipping via a pterional approach and ACoA aneurysms are already known to present an increased risk to olfaction. Aydin et al. revealed that 15% of patients with an ACoA aneurysm developed unilateral or bilateral olfactory dysfunction. Additionally, in a previous Sniffin’ Sticks test, 14% of patients with a ruptured ACoA aneurysm had abnormal binostril olfaction after a pterional approach.

Older age has also been identified in several studies as a risk factor to olfaction after surgical clipping of a ruptured aneurysm. Similarly, the current authors discovered a higher incidence of olfactory dysfunction after SAH in patients aged ≥ 55 years. Yet, in the present study of patients with unruptured ACoA aneurysms, age did not reach statistical significance as a risk factor.

The effect of a brain retractor on the olfactory nerve differs according to a pterional or superciliary approach. In the case of a superciliary approach, the retractor compresses the olfactory nerve to a greater extent than with a pterional approach, thereby risking the ipsilateral olfactory nerve. However, in the current study, the effect on binostril olfaction appeared to be similar between the pterional and superciliary approaches. Yet, selective damage to a unilateral olfactory nerve cannot be perceived with dual-nostril sniffing.

For patients with an ACoA aneurysm, frontal lobe retraction should be intermittent and limited to ≤ 1.5 cm with cerebral protection using cotton paddies to preserve the olfactory nerve. In addition, for patients with an estimated brain retraction > 12 mm, additional surgical procedures, instead of a simple pterional or superciliary approach, can be considered to preserve the olfactory nerve. An orbital osteotomy or orbitozygomatic approach involves a lower approach angle and provides increased space for the surgeon to work, thereby reducing the retraction of the frontal lobe and olfactory nerve. Plus, arachnoid dissection and mobilization of the olfactory nerve can release it from retraction.

The current study has several important limitations. First, it was based on a retrospective review of a small case series from a single institution. Thus, previously known risk factors associated with olfactory dysfunction, including age and a history of SAH, were not validated in this data set. Yet, although this study requires validation in a large prospective cohort, it still provides powerful predictors of postoperative olfactory dysfunction with statistical significance and a high AUC value. Second, the surgical procedures were performed using a self-retaining retractor system. Thus, the results may not apply when surgeons use a retractorless technique. In addition, the surgical techniques and results are too varied among different centers to make generalizations, but high-risk patients can still be identified with the proposed risk factors. Third, the Sniffin’ Sticks test was only applied to those patients who complained of significant olfactory dysfunction. In addition, the surgical techniques and results are too varied among different centers to make generalizations, but high-risk patients can still be identified with the proposed risk factors. Fourth, the Sniffin’ Sticks test was performed using dual-nostril sniffing rather than testing each nostril separately. Thus, no selective unilateral olfactory dysfunction was found in this study. Nonetheless, binostril smelling is more important to quality of life and much easier to evaluate. Fifth, the surgical approach, pterional versus superciliary, was not randomized among the patients. Thus, its effect on olfactory function needs further study. Future studies should also focus on the results and effects of an orbital osteotomy and olfactory nerve dissection on the olfactory nerve.
function of patients with an estimated brain retraction > 12 mm.

Conclusions

In cases of unruptured ACoA aneurysm surgery, the height of the aneurysm neck and the estimated extent of brain retraction were found to be powerful predictors of the occurrence of postoperative olfactory dysfunction.

References


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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