Supraorbital Ethmoid Cell: A Consistent Landmark for Endoscopic Identification of the Anterior Ethmoidal Artery

David W. Jang, MD¹, Vasileios A. Lachanas, MD, PhD¹, Lauren C. White, MD¹, and Stilianos E. Kountakis, MD, PhD¹

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Abstract
Objective. To demonstrate that the supraorbital ethmoid cell (SOEC) is a consistent and reliable landmark in identification of the anterior ethmoidal artery (AEA).

Study Design. Retrospective radiographic study.

Setting. Tertiary care rhinology practice.

Subjects and Methods. The computed tomography (CT) scans for 78 consecutive patients were evaluated for the presence of SOECs, degree of pneumatization, and location of the AEA in relation to fixed anatomic structures. Forty-one patients with normal SOECs were identified and compared with a group of 15 patients with pathological expansion of the SOEC secondary to inflammatory disease. The CT findings were correlated with endoscopic findings.

Results. The incidence of SOECs was 53%. Compared to normal SOECs, expanded SOECs had significantly greater pneumatization laterally (9.3 vs 18.5 mm, respectively; \( P < .0001 \)) and AEs that were significantly farther from the skull base (1.3 vs 6.6 mm, respectively; \( P < .0001 \)). The distance between the AEA and the nasal beak was similar between the 2 groups (\( P = .1 \)). More importantly, 68 of 68 sides with normal SOECs (100%) demonstrated the AEA within or in continuity with the posterior border of the SOEC opening. In patients with pathological expansion, the AEA remained within the posterior border of the SOEC opening in 19 of 19 sides (100%), despite significant expansion of the cell superolaterally.

Conclusion. This is the first study to demonstrate a consistent landmark to identify the AEA even in cases of distorted anatomy of the frontal recess. Identifying the SOEC is a practical and reliable technique for minimizing the risk of injury to the AEA during frontal recess surgery.

Keywords
supraorbital ethmoid cell, anterior ethmoidal artery, frontal recess, endoscopic sinus surgery

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Successful endoscopic frontal sinus surgery depends on the thorough removal of bony septations within the frontal recess. At the same time, the surgeon must be mindful of possible complications such as cerebrospinal fluid leaks and bleeding from the anterior ethmoidal artery (AEA). Violation of the AEA can be especially troublesome if the cut end of the vessel retracts into the orbit and causes an orbital hematoma. The location of the AEA has been reported to be highly variable in terms of its distance from the frontal sinus and its distance from the anterior skull base. Despite several cadaveric and radiographic studies that have looked into the endoscopic anatomy of the AEA, a consistent landmark for its identification has not been reported. Moreover, identification of the AEA becomes much more difficult in the setting of severe inflammatory disease of the frontal recess. An expanded supraorbital ethmoid cell (SOEC) refers to an SOEC that has undergone obvious gross expansion due to disease. We propose that the SOEC may serve as a consistent landmark for endoscopic identification of the AEA even in the setting of severe inflammatory disease.

Methods
Approval for this study was granted by the Georgia Regents University institutional review board. All the patients seen within a 3-month period (July to September 2012) in the senior author’s (S.E.K.) tertiary care rhinology practice were identified. Seventy-eight consecutive patients with standard spiral computed tomography (CT) scans of the paranasal sinuses demonstrating no expansile or erosive

¹Department of Otolaryngology—Head and Neck Surgery, Georgia Health Sciences University, Augusta, Georgia, USA

Corresponding Author:
David W. Jang, MD, Division of Otolaryngology—Head and Neck Surgery, Department of Surgery, Duke University, DUMC 3805, Durham, NC 27710, USA.

Email: david.jang@duke.edu
pathology were included in this study. All CT scans were performed at the same institution and consisted of 1-mm axial cuts with reformatted coronal and sagittal views. Radiological measurements were conducted using the software functions of the institutional PACS system (Carestream Health Inc, Rochester, New York, USA).

The CT scans were evaluated on coronal, axial, and sagittal sections for the presence of an SOEC, defined by Van Alyea\(^1\) as a cell produced by superolateral pneumatization of the orbital plate of the frontal bone. We included more stringent criteria for an SOEC for the purposes of our study. An SOEC was defined as the ethmoid cell immediately posterior and lateral to the frontal ostium with lateral pneumatization beyond the plane of the most medial portion of the lamina papyracea. The AEA was also localized on all 3 planes. For the subset of CT scans demonstrating an SOEC, the following measurements were performed: (1) the most lateral extent of the SOEC using the most medial portion of the lamina papyracea on the same coronal cut as a reference point (Figure 1A), (2) the distance between the AEA as it exits the lamina papyracea and the nasal beak as seen on a sagittal section (Figure 1B), (3) the distance between the AEA and the skull base as seen on a coronal section (as defined by the vertical distance from the midpoint of the intranasal portion of the AEA to the ethmoid roof) (Figure 1C), and (4) the location of the AEA in relation to the SOEC.

The CT scans with normal SOECs were then compared with a separate group of 15 CT scans (19 sides) that were known to have expansile pathology involving the SOEC. These scans demonstrating expanded SOECs were compiled from the senior author’s database over a 7-year period. The same measurements were then conducted for the expanded SOEC group and analyzed. The Student \(t\) test was used for statistical analysis. Values are reported as means with standard deviations and 95% confidence intervals.

**Results**

Forty-one of the 78 CT scans (53%) or 68 of the 156 sides (44%) demonstrated normal SOECs. The normal SOEC group consisted of 19 male and 22 female patients. Twenty-two were white, and 19 were black. The mean age was 50 ± 15 years. The mean extent of lateral pneumatization was 9.47 ± 5.66 mm. The mean distance between the AEA and the frontal beak was 17.36 ± 2.19 mm. The mean distance between the AEA and the skull base was 1.32 ± 1.51 mm. In all cases (68 of 68 sides), the AEA was located within the posterior border of the SOEC opening or within a bony septation extending from the posterior border of the opening as seen in Figure 2.
In the 19 sides (15 patients) of the expanded SOEC group, the expansile disease process affecting the SOEC consisted of allergic fungal sinusitis in 13 cases, mucoceles in 4 cases, polyps in 1 case, and fibrous dysplasia in 1 case. There were 11 male and 4 female patients and 10 blacks and 5 whites. The mean age was 37 ± 12 years. The mean extent of lateral pneumatization in this group was 18.52 ± 7.18 mm, the mean distance between the AEA and the frontal beak was 18.28 ± 2.05 mm, and the mean distance between the AEA and the skull base was 6.57 ± 5.17 mm.

The extent of lateral SOEC pneumatization and the distance between the AEA and the skull base were significantly higher (P < .001) in the expanded SOEC group. The AEA was found closely associated with the posterior border of the SOEC opening in all 19 cases.

Discussion

Numerous studies have contributed to the understanding of the surgical anatomy of the AEA. While most will agree that the AEA is usually located at the skull base between the second and third lamellae, published reports indicate that the exact location is highly variable within that area. A study by Lee et al looked at 56 cadaveric specimens found that the most consistent anatomic landmark for identifying the AEA was the axilla of the middle turbinate, which was found to be on average 20 mm from the AEA. However, the distance between this landmark and the AEA was shown to be anywhere in the range of 17 to 25 mm. A subsequent study by Han et al reported a lesser value of 17.5 mm as the mean distance between the axilla of the middle turbinate and the AEA. When examining the location of the AEA in relation to the superior attachment of the basal lamella, the same authors found no consistent relationship between these 2 structures.

Other anatomic relationships to help identify the AEA endoscopically have been reported in the last several years. A cadaveric study by Simmen et al showed that the AEA was located on average 11 mm from the posterior wall of the frontal recess, but this measurement ranged between 6 and 15 mm. While the majority of AEAs were in the suprabullar or supraorbital recess, some were found in the retrobullar recess or within the roof of the ethmoid bulla. Another cadaveric study by Yang et al reported that although the majority of AEAs were located between the second and third lamellae, the AEA was also found more frequently between the second and third lamellae.

| Table 1. Demographic Information and SOEC Measurements. |
|---------------------------------|-----------------|-----------------|-----------------|
|                                | Normal SOEC     | Expanded SOEC   | P Value         |
|                                | Group (n = 41)  | Group (n = 15)  |                 |
| Age, mean ± SD, y              | 50 ± 15         | 37 ± 12         |                 |
| Sex, n (%)                     |                 |                 |                 |
| Male                           | 19 (46.3)       | 11 (73.3)       |                 |
| Female                         | 22 (53.7)       | 4 (26.7)        |                 |
| Race, n (%)                    |                 |                 |                 |
| White                          | 22 (53.7)       | 5 (33.3)        |                 |
| Black                          | 19 (46.3)       | 10 (66.7)       |                 |
| Extent of lateral pneumatization of SOEC, mean ± SD (95% CI), mm | 9.47 ± 5.66 (8.12-10.81) | 18.52 ± 7.18 (15.30-21.75) | <.001 |
| Distance between AEA and frontal beak, mean ± SD (95% CI), mm | 17.36 ± 2.19 (16.84-17.88) | 18.28 ± 2.05 (17.37-19.21) | .106 |
| Distance between AEA and skull base, mean ± SD (95% CI), mm | 1.32 ± 1.51 (0.96-1.68) | 6.57 ± 5.17 (4.24-8.89) | <.001 |

Abbreviations: AEA, anterior ethmoidal artery; CI, confidence interval; SD, standard deviation; SOEC, supraorbital ethmoid cell.

*A The P value is significant at < .05.
anteriorly within the roof of the frontal recess and more posteriorly in the posterior ethmoid cavity.

In addition to its variability along the anterior to posterior dimension of the skull base, the AEA travels below the level of the skull base in some cases and has even been found to be dehiscent, adding another element of complexity to its anatomy. Studies report that the AEA travels within a bony mesentery below the level of the skull base in up to 36% of cases, with a dehiscence rate ranging from 6% to 66%. Several authors have pointed out that a long lateral lamella or the presence of supraorbital pneumatization was highly predictive of a low hanging AEA.

The relationship between the AEA and the SOEC was further explored by Zhang et al., who found that the AEA was always located posterior to the SOEC. However, they reported only a 5.4% incidence of SOECs in their study population of 202 Chinese subjects. This would have rendered the SOEC as an insignificant landmark because of its low incidence, but studies in Western populations have found a very high incidence of SOECs. In a study by Cho et al., the incidence of SOECs in a Korean population was 2.6%, while the incidence in a Western population was 64.4%. Our study of 78 consecutive CT scans found an incidence of 53.3%, which suggests that the supraorbital cell could serve as a highly useful landmark for identification of the AEA.

Like previous studies, we found that the location of the AEA was variable in terms of its absolute distance from a fixed anatomic structure, namely, the frontal beak in our study. Moreover, these anatomic relationships may become distorted in the setting of expansile disease. We also found that the extent of supraorbital pneumatization or expansion predicted the distance between the AEA and the skull base. This is strongly suggested by the significant difference in the extent of pneumatization and the AEA distance from the skull base in the expanded SOEC group. These observations further support the notion that the AEA has an uncertain location and is therefore highly vulnerable to injury. However, our study offers a consistent anatomic relationship between the AEA and the posterior wall of the SOEC that holds true even in the presence of distorted anatomy. One shortcoming of our study is that we base this conclusion on only 19 cases of expanded SOECs. Selection bias is also a possibility in that a highly distorted frontal recess cell can be labeled as an SOEC based on its relation to the AEA.

In the presence of SOECs, we suggest a stepwise approach to difficult cases involving the frontal recess. Early endoscopic identification of the frontal sinus outflow tract will allow subsequent identification of the SOEC opening, which is located immediately posterior and lateral to the frontal sinus. Once the SOEC is identified, the surgeon can safely assume that the AEA is located within the septation extending from the posterior aspect of the SOEC opening. Removal of the remainder of the frontal recess cells can then proceed anterior to this septation. This method is also helpful in endoscopic approaches to the anterior cranial base, when the AEA often needs to be identified and ligated. One may argue that the use of an image guidance system allows for positive identification of the AEA intraoperatively. While this may be true, the AEA may not be readily identifiable on an image guidance system. The anterior ethmoidal foramen is usually visible as it forms a “beak” along the lamina papyracea. However, this is typically present only on a single cut and may not be identified at all in the setting of frontal recess disease. The SOEC, on the other hand, is easily identifiable with or without the use of a surgical navigation system.

**Conclusion**

The variable location of the AEA in relation to the frontal sinus, as well as its variable distance from the skull base, adds an element of complexity to endoscopic surgery of the frontal recess. Our findings demonstrate that the presence of an SOEC can serve as a consistent landmark by which to identify the AEA, even in cases of distorted anatomy of the frontal recess. This allows for safe and thorough frontal sinus surgery.

**Author Contributions**

David W. Jang, study design, data collection, and manuscript writing; Vasileios A. Lachanas, study design and manuscript editing; Lauren C. White, manuscript writing and editing and data collection and analysis; and Stilianos E. Kountakis, study design and manuscript editing.

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