

A Simple Clinical Application for Locating the Anterior Ethmoidal Artery Using the Anterior Ethmoidal Foramen and the Anterior Nasal Spine

Shuyi Xu, MD,* Jing Yang, BS,^{†‡§} Yang Yang, MD,^{||†} Xiaomin Li, BS,[†] Jinghua Qiu, BS,[¶] and Zhijian Yu, PhD[†]

Purpose: The anatomy and variations of the anterior ethmoidal artery (AEA) are clinically relevant. The anterior ethmoidal foramen (AEF) can be used to locate the initial site of the AEA, and the anterior nasal spine (ANS) is a constant bony marker in the anterior nasal atrium. However, there is no relevant research on AEF and ANS targeting the AEA. Hence, this study aimed to accurately locate the AEA through AEF and ANS using computed tomography.

Methods: A total of 120 (240 sides) sinus computed tomography scans were retrospectively selected and studied. The AEA was classified into grades I, II, and III group based on the relationship between the AEA and the skull base. The distance between AEF and ANS and the angle between AEF-ANS and the axial plane were measured.

Results: The average distance from AEF to ANS was 58.26 ± 3.64 mm, and the corresponding angle was 60.05 ± 5.93 degrees. The AEF-ANS distances and angles were negatively correlated with age. Moreover, the distances from AEF to ANS were significantly increased in the grade III group compared with the grade II group.

Conclusion: The measurements obtained in this study add anatomic knowledge that can serve as a better intraoperative localization method of the AEA, which can help surgeons avoid relative complications during endoscopic sinus surgery.

Key Words: anterior ethmoidal artery, anterior ethmoidal foramen, anterior nasal spine, computed tomography, multiplanar reconstruction

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From the *Department of Ophthalmology, Zhuhai Hospital affiliated with Jinan University (Zhuhai People's Hospital); †Department of Otolaryngology, Zhuhai People's Hospital (Zhuhai Hospital affiliated with Jinan University); ‡Zhuhai Hearing and Balance Center; §Hearing and Balance Center, Zhuhai Hospital of Integrated Traditional Chinese & Western Medicine; ||Zhuhai Interventional Medical Centre, Zhuhai People's Hospital (Zhuhai hospital affiliated with Jinan University); and ¶Department of Radiology, Zhuhai People's Hospital (Zhuhai Hospital affiliated with Jinan University) Zhuhai, China.

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S.X., J.Y., and Y.Y. contributed equally to the study.

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Address correspondence and reprint requests to Zhijian Yu, PhD, Department of Otolaryngology, Zhuhai People's Hospital (Zhuhai Hospital affiliated with Jinan University), No.79 Kangning Road, Xiangzhou District, Zhuhai 519000, Guangdong Province, China; E-mail: yzjent@163.com

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The anterior ethmoidal artery (AEA) is a structure of focus in endoscopic sinus surgery (ESS) and is regarded as an important landmark when locating the frontal sinus and the anterior skull base.¹⁻⁴ The AEA is a branch of the ophthalmic artery, which arises from the internal carotid artery. It is transmitted through the anterior ethmoidal foramen (AEF) on the medial wall of the orbit.² It then reaches the ethmoidal sinus, passing through the bony anterior ethmoidal canal (AEC), finally getting into the olfactory fossa through the lateral lamella of the cribriform plate.⁵ The AEA exhibits considerable variability in terms of distance from the frontal sinus and the skull base¹; it may be closely apposed to the skull base, or it may traverse the ethmoids, either freely or within a bony canal.^{6,7} Poor recognition of this variation places the artery at risk during ESS, as injury to the AEA may result in severe consequences such as massive hemorrhage, vision loss, peri-orbital or intraorbital hematoma, and cerebrospinal fluid rhinorrhea, among others.^{2,8} Therefore, detailed anatomic knowledge regarding the exact location of the AEA is necessary for safely performing ESS.

Preoperative paranasal sinus computed tomography (CT) evaluation has been considered a mainstay in surgical planning before endoscopic surgery to help avoid serious complications.⁹⁻¹¹ Indirect identification of the AEA using adjacent bony landmarks, such as the nasal beak,¹² the middle conchae axilla,¹³ and the ethmoid pneumatization,¹¹ on CT imaging and in cadaveric studies has been widely practiced. However, it is not practical to measure the respective lengths of these landmarks from the AEA during surgery. Navigation CT can be used in clinical operations,¹⁴ but it is difficult to popularize navigation equipment in primary hospitals because of its high price. The AEF is a good reference

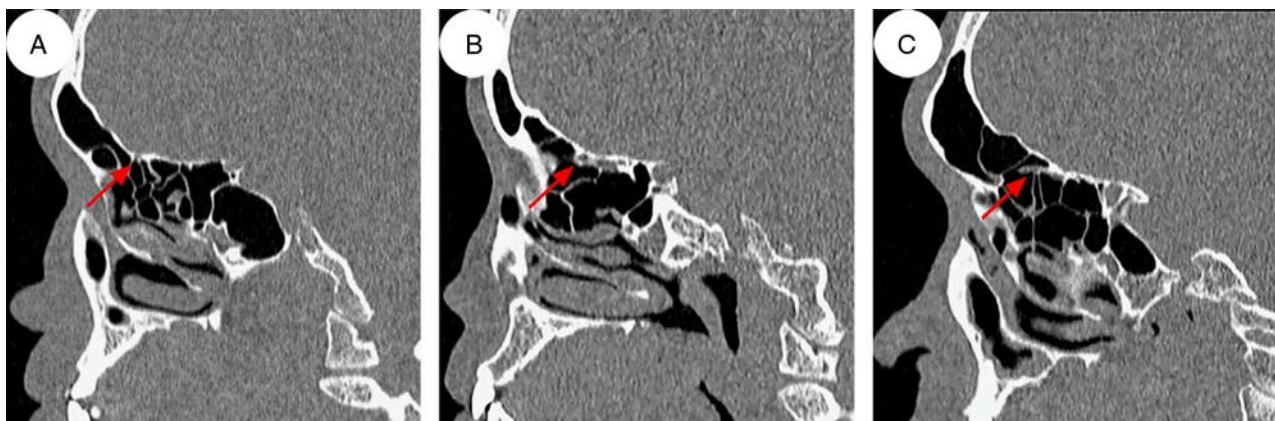


FIGURE 1. Sagittal CT images showing the 3 types of AEA (red arrows). (A) Grade I: within the roof; (B) Grade II: under the roof, considered as prominent; (C) Grade I: distant from the ethmoidal roof. AEA indicates anterior ethmoidal artery; CT, computed tomography.

for identifying the position and the orientation of the AEA within the ethmoid sinus.^{6,15} The anterior nasal spine (ANS) is a constant bony marker in the anterior nasal atrium. Presently, there are only a few studies examining the accurate location of the AEA with the help of the ANS and AEF during operations.

In this study, we present a reliable method of radiologically detecting the location of the starting position of the AEA by detecting distances and angles from the AEA to the ANS through CT scan, which will be useful for surgeons performing ESS.

MATERIALS AND METHODS

This study was approved by the local ethical committee, and informed consent was obtained from each subject. We retrospectively evaluated data from 120 patients (240 scans) who underwent sinus CT for suspected nasal and paranasal diseases between January 6, 2019 and June 30, 2019, at the Department of Otolaryngology, Zhuhai People’s Hospital, Zhuhai Hospital Affiliated with Jinan University. All available CT scans of the subjects were retrieved from the Radiology Information System and the Picture Archive Communication System of the institution. The inclusion criteria were CT scans with a slice thickness of 1 mm and capable of undergoing multiplanar reconstruction. The following exclusion criteria were applied: subject age younger than 18 years, previous surgery of the paranasal sinuses or skull base, nasal tumors, craniofacial anomalies, previous trauma to the paranasal sinuses or skull base, and severe rhinosinusitis that could have made the visualization of the bony trabeculae difficult on the CT scans.

The CT scans of all subjects were performed using a 128-banks multislice CT scanner (Siemens, Germany). Bone-view images were used for making the measurements. On multiplanar reconstruction, the 3 planes (axial, coronal, and sagittal) were seen simultaneously and allowed for measurements in the actual scale. We evaluated the distances and angles between the AEA at its entry point in the nasal cavity and the ANS in all patients. The measurements were done by 3 of the authors (S.Y.X., J.Y., and Y. Y.). They also simultaneously interpreted the CT scans and reached conclusions by consensus.

The AEA was identified and recorded as being either within the skull base or separated from the skull base. As described in a previous study,⁷ the position of the AEA in relation to the skull base was classified as follows: grade I, when AEA was embedded in the skull base; grade II, when the

AEA was prominent from the skull base; and grade III when the AEA was suspended below the skull base. Typical images of the different AEA types are shown in Figure 1.

We followed the steps below for making the measurements:

- (1) Determining the reference landmarks for measurement.

Point A (ie, the AEF) was identified as a bell-like structure formed medially between the superior oblique and the medial rectus muscles in the coronal plane. Point B was the intersection of the perpendicular line from point A and the sagittal plane. Point C was the point of intersection of the 3 planes. Point D (ie, the ANS) was the bony protuberance at the anterior and upper part of the maxilla in the sagittal view. Point E was the intersection of the perpendicular line from point A and the axial plane. The diagrammatic drawing with the specific measurement method is shown in Figure 2.

- (2) Measuring the distance between the AEF and ANS and the angle between AEF-ANS and the axial plane.

The AEF-ANS distance was defined as the distance from AEF (point A) to ANS (point D).

The AEF-ANS angle (ie, $\angle ADE$) was defined as the angle between the ANS-AEF line and the axial plane.

AB and BC were measured in the coronal position, whereas CD and AC were measured in the sagittal position. The angle between AB and BC and that between AC and CD were both right angles; hence, the distance from point A to D and the angle between AEF-ANS and the axial plane could be calculated using trigonometry.

The trigonometric formula can be written as follows:

$$AD = \frac{AE}{\sin \angle ADE} = \frac{BC}{\sin \angle ADE}$$

$$\angle ADE = \arcsin \frac{BC}{AD}$$

Statistical Analyses

All data obtained were expressed as mean, SD, and minimum and maximum values. Statistical significance was assessed using the Kruskal-Wallis *H* test and the nonparametric Mann-Whitney *U* test except for the addition note. The Spearman correlation test was used to determine the association between the AEF-ANS distance and age, as well as the association be-

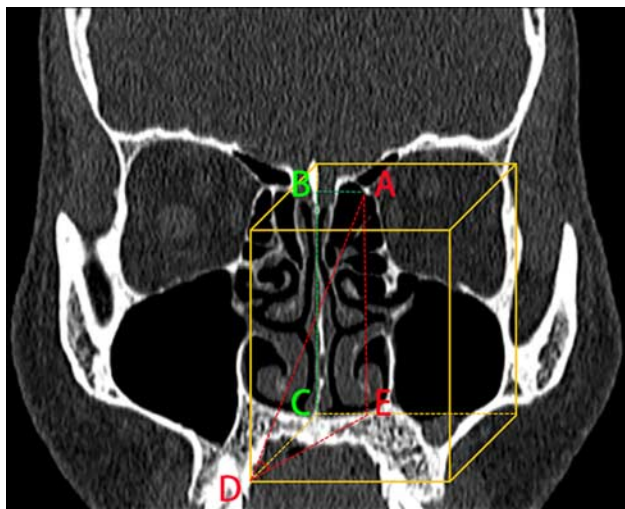


FIGURE 2. The 3-dimensional space between the ANS and the AEF was constructed. Point A, AEF; point D, ANS. AEF indicates anterior ethmoidal foramen; ANS, anterior nasal spine.

tween the AEF-ANS angle and age. A *P*-value of <0.05 was considered statistically significant.

RESULTS

The Distance and Angle From AEF to ANS

In this study, the AEF and ANS were observed in 100% of the cases. The average AEF-ANS distance and angle were 58.26 ± 3.64 mm and 60.05 ± 5.93 degrees, respectively. When comparing right and left measurements, no significant difference was found between the distances and angles on the 2 sides (Figs. 3A, B).

Relationship With Age

The subject ages ranged from 18 to 70 years, and the average age was 39.57 years. Since there was no significant difference in the AEF-ANS distances and angles concerning laterality, we compared the relationship between age in total and the AEF-ANS distances and angles. Our study demonstrated that the AEF-ANS distances and angles were negatively correlated with age (Fig. 4A, $r = 0.270$, $P = 0.000$; Fig. 4B, $r = 0.165$, $P = 0.010$).

Relationship With Different AEA Types

The AEA was found at the skull base (grades I and II) in 47.1% ($n = 113$) of cases. In 36% ($n = 87$) of these cases, the AEA was prominent within the skull base (grade II). Moreover, the AEA was below the skull base (grade III) in 127 (52.9%) cases. The AEF-ANS distances and angles among different AEA types are available in Supplemental Table 1 (Supplemental Digital Content 1, <http://links.lww.com/SCS/E106>). We found that the AEF-ANS distance was significantly higher in the grade III group compared with the grade II group (Fig. 5A). However, there was no significant difference in the AEF-ANS distance between the grades I and II groups, and between the grade I and grade III groups (Fig. 5A). Moreover, there was no significant difference in the AEF-ANS angle among the 3 groups (Fig. 5B).

DISCUSSION

In the present study, we accurately calculated the distance between AEF and ANS and the AEF-ANS angle using pre-operative sinus CT to accurately locate the starting position of the AEA. In addition, we found that the 2 measurements have no relation with laterality, but were related to gender and age. Furthermore, we also confirmed the relationship between the 2 measurements and the 3 AEA positions in relation to the skull base.

The identification of AEA is of major importance in locating the frontal sinus and defining the superior limit during skull base surgery to prevent unnecessary injury. Therefore, intraoperative localization of the AEA is of great significance. The AEC houses the AEA, and can, hence, be used to locate it.¹⁶ However, the AEA traverses the roof of the ethmoid sinus, often taking a posterolateral to anteromedial oblique route.¹⁷ Therefore, it is hard to exactly pinpoint the entire course of the AEA.

The AEF is the starting position of the AEC, which is clearly visible and serves as an initial parameter for the identification of the AEA.¹ The AEF can be found in 100% of CT scans,^{15,17} similar to what we observed in the present study. In the endonasal endoscopic view, finding the ethmoidal foramen is not easy; hence, it is necessary to identify correlations between the AEA and other structures to allow its safe identification. One radiological study located the AEA by measuring the distance of the AEF from the ethmoid bulla and the frontal beak.¹ However, the accurate measurement of these distances during surgery is difficult. The ANS is a consistent anatomic landmark that has been used by surgeons to identify the anterior skull base¹⁸ and the sphenoidal rostrum.¹⁹ The AEF-ANS distances

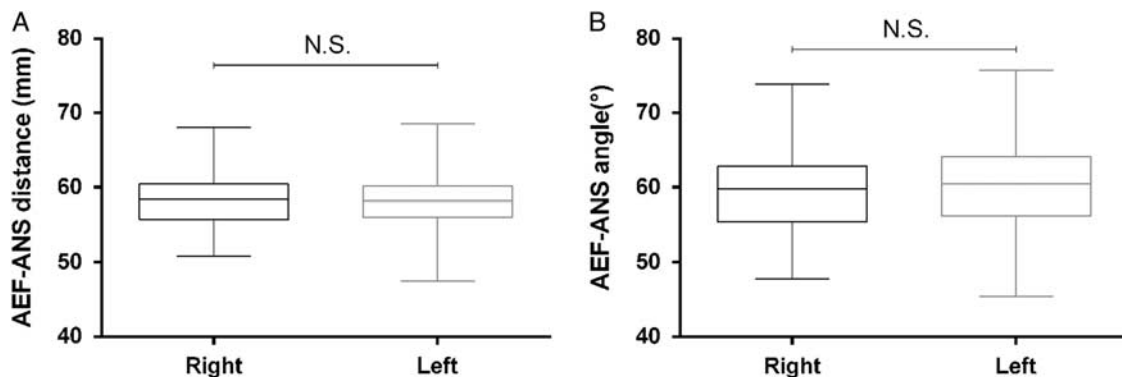


FIGURE 3. Comparison of the AEF-ANS distances (A) and angles (B) with respect to laterality. AEF indicates anterior ethmoidal foramen; ANS, anterior nasal spine; N.S., not significant.

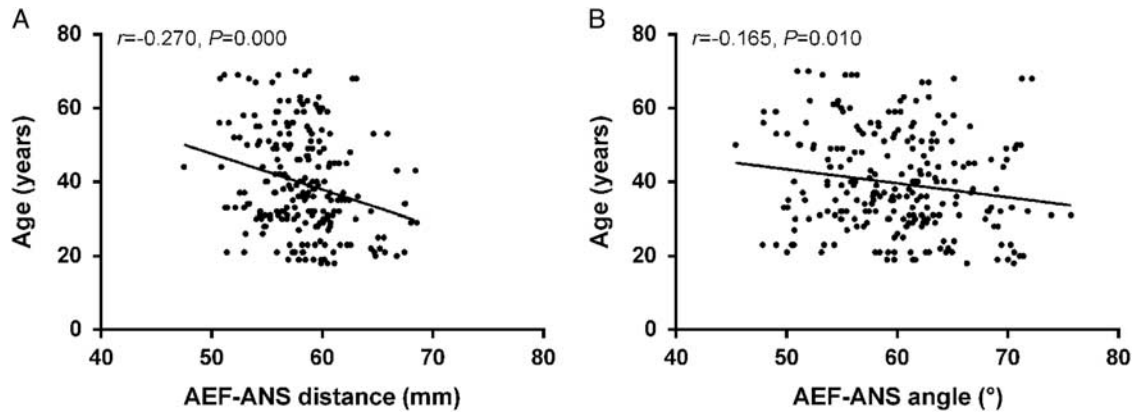


FIGURE 4. The AEF-ANS distances and angles were negatively correlated with age. (A) The correlation between the AEF-ANS distance and age in total ($r = -0.270$). (B) The correlation between the AEF-ANS angle and age in total ($r = -0.165$). AEF indicates anterior ethmoidal foramen; ANS, anterior nasal spine.

and angles that we measured in the present study can reliably serve as references to safely identify the starting position of the AEA. To the best of our knowledge, this is the first report of its kind.

We found that the average distance from AEF to ANS was 58.26 ± 3.64 mm, and the corresponding angle was 60.05 ± 5.93 degrees. Regarding laterality, no significant difference was observed among the analyzed measurements. These findings suggest that surgeons using the ANS as a reference for determining the orbital wall during ESS can use these distance and angle measurements while advancing their operating instruments along the orbital wall to reduce the risk of injury to the AEA. In addition, the location of the AEA helps to locate and protect the optic nerve. According to Habal et al’s²⁰ study, the distance between the AEA and the posterior ethmoidal artery is 12.30 mm, and the distance between the posterior ethmoidal artery and the optic nerve is 6.82 mm. Therefore, by determining of the position of the AEA, we can roughly locate the optic nerve, which is significant for optic nerve decompression surgery.

Morales-Avalos et al²¹ reported an age-related variation in the anteroposterior diameter of the medial wall of the orbit, with the distances from the AEF to the posterior ethmoidal foramen being significantly greater among individuals older than 40 years. In our study, we found that the AEF-ANS distances and angles were negative correlated with age. These

findings indicate that the position of the AEF may shift downward with increasing age, which also explains the increased distances between the AEF and the posterior ethmoidal foramen in individuals older than 40 years. In addition, with increasing age, the safe distance between the AEF and ANS and the AEF-ANS angle would reduce, which must be taken into consideration intraoperatively.

Several anatomic variations of the AEA have been previously described. In this study, the AEA was at the skull base in 47.1% of cases, and was located below the skull base in the remainder of the cases. These findings were comparable to a previous study by Yenigun et al²² wherein the AEA was at the skull base in 47.2% of their cases. On the contrary, 76.8% of cases in a study by Guarnizo et al,⁸ and 85.7% of cases in a study by Moon et al,¹⁶ reported the AEA as being at the skull base. These discrepancies in terms of frequencies may be related to interracial differences. In the present study, we evaluated whether the AEF-ANS distances and angles are altered among the 3 AEA positions. We found that the AEF-ANS distance in subjects with grade III AEA position was significantly higher than that in the grade II group. Conversely, the corresponding angle in the grade III group was lower than in the grade II group, though not significantly. These findings indicate that the AEF in the grade III group was deeper, implying that the grade III AEA may be more easily exposed under a 0-degree endoscope during ESS.

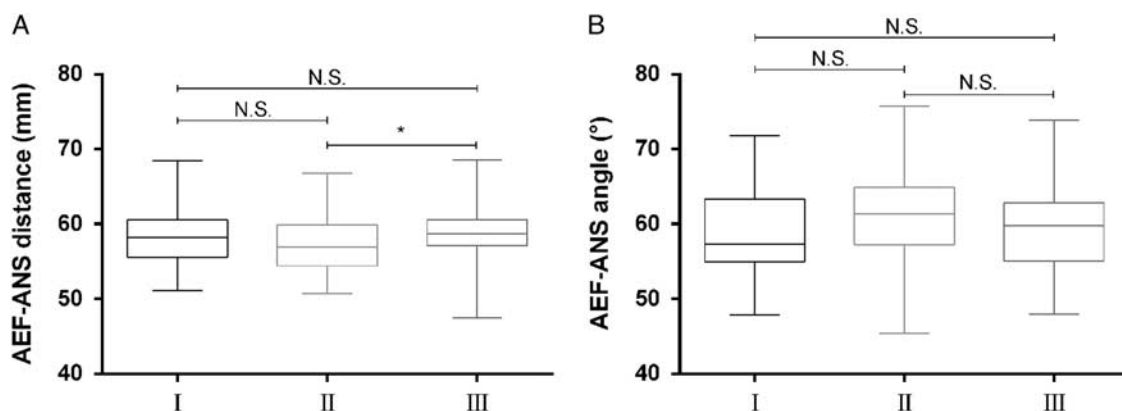


FIGURE 5. Comparison of the AEF-ANS distances (A) and angles (B) with respect to different AEA types. AEA indicates anterior ethmoidal artery; AEF, anterior ethmoidal foramen; ANS, anterior nasal spine; N.S., not significant. * $P < 0.05$.

A limitation of our study was the measurement of the AEF-ANS distances and angles were done on CT scans. Because the ANS is covered by mucosa, the thickness of the mucosa may have affected the accuracy of the distance measurements. Therefore, surgeons should consider adding the mucosa thickness to the distance estimate during the operation. In addition, we acknowledge that this is an observational clinical study with a small sample size, and that potential bias cannot be completely excluded.

CONCLUSION

Taken together, these findings may contribute to the establishment of a better intraoperative localization method for the AEA. Our measurements can be used to help surgeons conveniently and easily locate anatomic landmarks.

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