İstanbul Med J 2024; 25(1): 67-71
DOI: 10.4274/imj.galenos.2024.88225

Evaluation of the Anterior Ethmoidal Artery Course in Pediatric Patients

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ABSTRACT

Introduction: The anterior ethmoidal artery (AEA) is an important structure to be considered in endoscopic endonasal surgery, which can lead to serious complications due to injury. We aimed to reveal AEA's course and age-dependent variations and the relationship with closely related structures in pediatric cases.

Methods: The paranasal sinus computed tomography of patients under 18 years was retrospectively reviewed. The coronal reformated plane, which is perpendicular to the hard palate, was used for measurements. The AEA was assessed for its course at or below the skull base, and the distance was measured. In addition, the depth of the olfactory fossa (DOF) and nasal septal deviation (NSD) were measured.

Results: A total of 156 patients were enrolled in this study. As the DOF increases, the AEA skull base distance also increases ($p<0.005$). In addition, both DOF ($p=0.014$) and AEA skull base distance ($p=0.004$) increase with age. The age of the patients with NSD was higher than that of the patients without deviation ($p=0.035$). Although not statistically significant, a slight increase in both AEA skull base distance and DOF was noted on the NSD side ($p>0.05$).

Conclusion: These results show that the olfactory roof anatomy and NSD are not only related to the embryonic period but also an ongoing process after birth.

Keywords: Anterior ethmoidal artery, pediatric, skull base, ethmoid roof, nasal septal deviation, olfactor fossa

Introduction

Revealing the anatomy of the anterior skull base and ethmoid roof has become essential with endoscopic endonasal surgery (1). The endoscopic endonasal approach is increasingly used in current medical practice for skull base, nasal cavity, orbit, or paranasal sinus surgery (2,3). The anterior ethmoidal artery (AEA) is an important landmark for surgeons in endoscopic surgery (4,5). The anatomy of the anterior skull base can be revealed in detail preoperatively using computed tomography (CT) (6). There are three detection points of the AEA on the skull base: the anterior ethmoidal foramen (on the medial orbital wall), the anterior ethmoidal canal (in the anterior ethmoidal sinus or skull base), and the anterior ethmoidal sulcus (on the lateral lamella of the cribriform plate) (4,7-9). Incidental injury of AEA during endoscopic surgery can cause fatal complications such as hematoma or vision loss. The relevant anatomy and location of the AEA need to be revealed individually before surgery to avoid these complications (4,10).

The olfactory fossa is susceptible to injury during endoscopic surgery such as AEA and is closely related to AEA. Different studies have been conducted to reveal and predict the risks of complications in this area during endoscopic surgery (11-13). Keros (12) defined a widely accepted classification of the depth of the olfactory fossa (DOF) to predict complications. They classified the depth of the fossa into three groups: deepest type 3, intermediate 2, and shoaliest type 1 (12).

The nasal septum is another structure related to the ethmoid roof. It runs down from the anterior skull base to the palatine bone. Nasal septal deviation (NSD) may be associated with asymmetries of related areas such as the palatine area and nasal roof (14,15).

Endoscopic endonasal surgeries are in use at increasing rates, especially in the pediatric population, because of their advantages (16,17). The relationships of anatomic structures of the skull base can be more complex because of the nearing locations of landmarks and the continuing process of development and ossification in the pediatric population (18,19). Therefore, surgeons might pay extra attention to revealing the variations of the skull base preoperatively in pediatric cases.

Distinct studies were conducted to reveal the anatomic relationships and variations for predicting and avoiding the complications of endoscopic surgery. However, most of these studies were conducted in

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Received: 31.01.2024
Accepted: 07.02.2024
Cite this article as: Aksoy DÖ. Evaluation of the Anterior Ethmoidal Artery Course in Pediatric Patients. İstanbul Med J 2024; 25(1): 67-71.

adults (2,10,15,20,21). This study reveals the course of AEA and age-dependent variations in pediatric cases. The second aim was to reveal the relationship between AEA and the olfactory fossa and nasal septum, which are structures closely related to AEA.

Methods

Data Collection

The University of Health Sciences Turkey, İstanbul Training and Research Hospital Institutional Ethical Review Board approval was obtained for this study (approval number: 59, date: 10.03.2023). We scanned the hospital archive system retrospectively for patients who underwent paranasal CT from January 2020 to January 2023. We enrolled the CT images of pediatric patients (age; ≤18) with slice thickness equal to or less than 1 mm, which is suitable for reconstruction with multiplanar reformat imaging. The exclusion criteria were craniofacial anomaly, trauma with fracture, history of surgery, sinonasal tumor, fibro-osseous mass lesions, or other situations that distort the maxillofacial or skull base area.

CT Imaging and Radiological Measurements

CT images were acquired with a 64-slice CT scanner (MSCT; Brilliance 64, Philips Medical System, Best, Netherlands). All scans were obtained as routine CT of paranasal sinus imaging in the supine position. The scanning protocol was caudocranial in extent from the hard palate to the end of the frontal sinus, with a field of view of approximately 140-160 mm. The slice thickness was 0.67-1 mm with automatic exposure at 120 kVp and 80-140 mAs. Multiplanar reconstruction was performed with the bone kernel (Widow Wide: 3000-4000 HU, Window Center: 300-500 HU) in three-dimensional (axial, coronal and sagittal) plans. Images were evaluated using the picture archiving and communication system, and coronal plane images perpendicular to the hard palate were used for measurements. All assessments and measurements in this study were performed by the same radiologist (D.Ö.A.). First, the location of the AEA was revealed relative to the anterior ethmoidal foramen. The anterior ethmoidal canal was identified and recorded to determine whether the trace of the canal was in the skull base or under the skull base (4,7,8) (Figure 1A). The distance between the skull base and anterior ethmoidal canal was measured if the trace was under the skull base. The distance between the cribriform plate and the horizontal line passing through the superolateral end of the lateral lamella was measured as the height of the olfactory fossa (22) (Figure 1B). DOF was graded as Keros type 1 (<4 mm), Keros type 2 (4-7 mm), and Keros type 3 (>7 mm) as defined by the Keros classification (12). The cases were evaluated for the presence of NSD. If NSD was present, the side of the angulation was recorded and the deviation angle was calculated. The NSD angle was measured where the angulation of the nasal septum was the most on the coronal plane according to the line extending from the crista galli to the crista nasalis (Figure 1C) (23). All measurements and classifications were performed on either the right or left side.

Statistical Analysis

The mean, median, minimum, maximum, and standard deviation frequency and percentage were used for descriptive statistics. The distribution of variables was checked using the Kolmogorov-Smirnov test. The Kruskal-Wallis test and Mann-Whitney U test were used for the comparison of quantitative data. The chi-square test was used to compare the qualitative data. Correlation between variables was tested with Spearman's correlation. SPSS 28.0 was used for statistical analyses.

Results

A total of 156 patients were enrolled in the study after excluding cases that met the exclusion criteria mentioned above. There were 81 female and 75 male patients. The mean age was 7.65±4.07 years. The AEA canal passes through the skull base on 109 of the right side and 111 of the left side. When the right and left sides were included in the evaluation separately, 71% of the 312 sides coursed at the skull base, whereas 29% were freely under the skull base. The mean value of the distance from the skull base was 0.36±0.70 mm (right: 0.38±0.70, left: 0.34±0.69) of the AEA canal in all patients. NSD was not detected in 61 patients. The

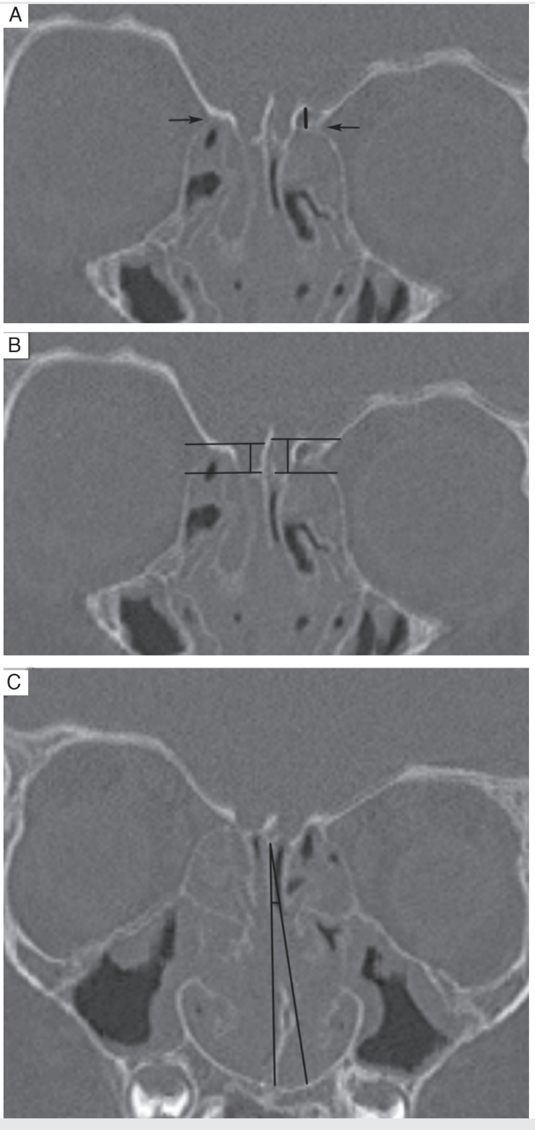

Figure 1. Assessment and measurements of the anterior ethmoidal artery (AEA course at the skull base on the right and below the skull base on the left) (A), olfactory fossa depth (B), and nasal septal deviation (C)

deviation side was to the right in 55 patients and left in 40, of a total of 95 patients who had NSD. The mean DOF was 4.23±1.88 on the right and 4.23±1.91 on the left. When we classified the DOF of both sides, we observed 131 (60 right, 71 left) Keros type 1, 163 (86 right, 77 left) Keros type 2, and 18 (10 right, 8 left) Keros type 3.

There was a positive correlation between age, distance of AEA to the skull base, and DOF (Table 1). The mean age of the patients with NSD (8.24±4.11) was higher than that of the patients without NSD (6.74±3.85) (p=0.035) (Table 2). The mean value of the right-sided deviation was 10.34±5.07 degrees and the left-sided deviation were 13.16±4.69. The degree of the left side was higher than that of the right side degree (p=0.02). We did not detect any significant difference between the side of the NSD and the depths of the olfactory fossa or the distance of the AEA from the skull base for both sides (Table 3). The AEA distance was significantly higher in the Keros Type 3 group than in the Keros type 1 and type 2 (p<0.05). In addition, in the Keros type 2 group, it was significantly higher than in Keros type 1 (p<0.05). The mean distances of AEA to the skull base of Keros types are summarized in Table 4.

Discussion

Preoperative imaging of the ethmoid roof and the identification of anatomical landmarks are crucial for endonasal surgery (24). A variation that might be seen in the anatomy of this area is a situation that may challenge surgery. Awareness of anatomical variations helps prevent vital complications such as bleeding or skull base injury. In particular, in children, the close location of the relevant anatomical structures is another challenging situation and requires more attention (16,25). CT is an appropriate and accepted imaging method for defining the nasal, paranasal, and ethmoid roof areas (10,26).

One of the dangerous parts of the ethmoid roof and one of the landmarks for endoscopic surgery is the AEA (21,26,27). The location of the AEA shows variability individually (26). In particular, the AEA, which runs below the skull base, is more susceptible to injury (7,28). In their study on cadavers (ages not stated), Simmen et al. (26) showed that the AEA was located below the skull base in 35% of the cases. Başak et al. (29) found that 43% of the AEA traces were below the skull base in their study of cases over 15. In another study conducted by Başak et al. (30), including some of the same authors, it was stated that the AEA extends below the skull base in 26% of cases between the ages of 8 and 16. They also compared the results of these two studies and detected a significant difference between young and adults during AEA (p=0.004) (30). Another study stated that the course of AEA at the skull base was more common in cases under 18 years than in those over 18 years (49% vs. 44%; p=0.024) (3). In this study, the AEA trace was found at the skull base in 71% of the pediatric cases. The percentage we obtained is closer to that of studies conducted with pediatric cases in the literature. The mean distance of the AEA from the skull base was different in different studies. The mean value was 1.93 mm (18-86 years, range: 0-7.50 mm) in the study of Abdullah et al. (10), 3.5 mm (cadaver unknown, range 1-8 mm) in the study of Simmen et al. (26), 1.37 mm (18-66 years, range: 0-8.35 mm) in the study of El Anwar et al. (2), and 2.40 (adult, range: 0-8.20) in the study of Naidu et al. (20). The mean distance from the skull base was 0.36±0.70 mm (0-18, range: 0-3.8 mm) in this study. The

Table 1. Correlation analysis of the distance of the anterior ethmoidal artery from the skull base and the depths of the olfactory fossa

	DOF (mm)		AEA (mm)	
	r	p	r	p
Age	0.197	**0.014**	0.232	**0.004**
DOF (mm)			0.248	**0.000**

Spearman xorrelation AEA: Anterior ethmoidal artery, DOF: Depth of the olfactory fossa

Table 2. Mean age and gender of NSD (+) (with nasal septal deviation) and NSD (-) (without nasal septal deviation) patients

		NSD (-)		NSD (+)		p
		Mean ± SD/(n, %)	Median	Mean ± SD/(n, %)	Median	
Age		6.74±3.85	6.00	8.24±4.11	8.00	**0.035**^{m}
Gender	Female	30 (49.2%)		51 (53.7%)		0.583$^{X^2}$
	Male	31 (50.8%)		44 (46.3%)		

$^{X^2}$Chi-square test, ^{m}: Mann-Whitney U test, NSD: Nasal septal deviation, SD: Standard deviation

Table 3. Depths of the olfactory fossa and distance of the anterior ethmoidal artery from the skull base for both sides of each (right and left) side of nasal septal deviation

		Left side NSD		Right side NSD		p
		Mean ± SD	Median	Mean ± SD	Median	
Age		8.65±4.01	8.00	7.68±4.24	6.00	0.193^{m}
Gender	Female	30 (54.5%)		21 (52.5%)		0.844$^{X^2}$
	Male	25 (45.5%)		19 (47.5%)		
AEA-R (mm)		0.50±0.75	0.00	0.34±0.81	0.00	0.075^{m}
AEA-L (mm)		0.32±0.54	0.00	0.44±1.05	0.00	0.400^{m}
DOF-R (mm)		4.70±1.87	4.50	4.24±2.02	3.80	0.195^{m}
DOF-L (mm)		4.35±1.74	4.20	4.63±2.56	3.85	0.955^{m}

$^{X^2}$: Chi-square test, ^{m}: Mann-Whitney U test, AEA: Anterior ethmoidal artery, DOF: Depth of the olfactory fossa, SD: Standard deviation, NSD: Nasal septal deviation

Table 4. Mean distances of AEA to the skull base of Keros types					
		Keros type 1	Keros type 2	Keros type 3	p
AEA (mm)	Mean ± SD	0.21±0.57	0.44±0.76	0.71±0.73	**0.001**[K]
	Median	0.00	0.00	0.70	

[K]: Kruskal-Wallis (Mann-Whitney U test), AEA: Anterior ethmoidal artery, SD: Standard deviation

difference from the literature in the mean distance of the AEA to the skull base in our population might be related to the age distribution and therefore the higher incidence of the skull base coursing of AEA. We also obtained a significant ($p<0.05$) positive correlation between age and the distance of AEA to the skull base, supporting this claim. We can assume that we may see the skull base course of AEA more frequently at an early age because of the ongoing process of the development of the skull base and ventilation of the paranasal sinuses in children.

Patients with a higher DOF are defined as having a higher accidental injury risk during surgery (12). It has been emphasized that the relationship between the olfactory fossa and AEA may be related to the intraoperative bleeding risk profile (3). In this study and the literature, both the distance of the AEA to the skull base and DOF increase with age, supporting that the development of the AEA trace and DOF are correlated with each other (1,3,31). DOF could be a reliable predictor of the course of AEA at the ethmoid roof (10,32). The relationship between the DOF and the location of the AEA was found to be significant ($p=0.016$) (10). In the study of Poteet et al. (32), AEA was located below the skull base in 55% of Keros type 3 cases, 29.5% of Keros type 2 cases, and 0% of Keros type 1 cases. In addition, the distance of the AEA from the skull base was significantly higher in Keros type 3 patients than in Keros type 2 patients (4.55 vs. 3.42 mm, $p=0.001$) (32). There was a positive correlation between DOF and the distance of the AEA trace from the skull base ($p<0.005$), in this study. The distance of the AEA course to the skull base was significantly higher in the Keros type 3 group (0.71±0.73) than in the Keros type 2 group (0.44±0.76) ($p<0.05$), and in the Keros Type 2 group than in the Keros Type 1 group (0.21±0.57) ($p<0.05$) (Table 4). These results show that with increasing DOF, the likelihood of the course of AEA within the ethmoid sinus increases.

NSD, particularly the high degrees, is a situation that challenges endoscopic sinus surgery. The nasal septum is also associated with the ethmoid roof; therefore, anterior skull base variations may be associated with NSD (33). Deviation was detected in 60.9% of our patients, and no significant gender difference was detected. However, the mean age of the patients with NSD was higher (8.24±4.11) than that of the patients without NSD (6.74±3.85) ($p=0.035$). Although nasal septal angulation can be observed in the embryological period, our results support the hypothesis that nasal septal angulation may continue in early childhood. When the right and left sides of the AEA-skull base distance and DOF values were evaluated separately according to the NSD side, no significant difference was detected (Table 3). However, it was noted that the AEA skull base distance and DOF were higher on the deviation side, although they did not reach statistically significant levels. We did not encounter any article in English comparing the course of AEA and nasal septal angulation in the literature. Onerci Altunay and Onerci (33) did not detect a significant difference in terms of cribriform depth ($p=0.713$) and Keros distribution ($p=0.514$) on the deviation side and the contralateral side. Bayrak et al. (34) and Özeren Keşkek and Aytuğar (35) also found no significant relationship between NSD and olfactory fossa depth ($p>0.005$).

Study Limitations

This study has some limitations. Because this was a retrospectively planned study considering the effects of radiation on the pediatric population, the number of cases was limited and could not be increased. A single radiologist performed the measurements, and the intraobserver or interobserver variation was not examined.

Conclusion

This study revealed age-related differences in the AEA course and the relationship of related structures such as the olfactory fossa and nasal septum with AEA. As the DOF increases, the AEA skull base distance also increases ($p<0.005$). In addition, both DOF ($p=0.014$) and AEA skull base distance ($p=0.004$) increase with age. We found that the age of the patients with NSD was higher than that of the patients without ($p=0.035$). Although no significant difference was detected in the AEA skull base distance or DOF on the NSD side, a slight increase in both AEA skull base distance and DOF was noted on the NSD side ($p>0.05$). These results show that olfactory roof anatomy and nasal septum deviation are not only related to the embryonic period but are also a process that continues after birth.

Ethics Committee Approval: The University of Health Sciences Turkey, İstanbul Training and Research Hospital Institutional Ethical Review Board approval was obtained for this study (approval number: 59, date: 10.03.2023).

Informed Consent: Retrospectively study.

Financial Disclosure: The author declared that this study received no financial support.

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