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ORIGINAL ARTICLE

Anterior ethmoidal artery at ethmoidal labyrinth: Bibliographical review of anatomical variants and references for endoscopic surgery

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KEYWORDS
Anterior ethmoidal artery;
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Abstract
Introduction: The anterior ethmoidal artery (AEA) has a trajectory with multiple anatomical variations. In addition, there are no clear references to locate it, so it is easy to produce an iatrogenic lesion. The goal of this study was to carry out a bibliographical review to analyse variants and endoscopic reference reports in the scientific literature.
Material and methods: A review in Medline and Embase data bases was carried out, looking for AEA-related anatomical and radiological studies. After the revision, the principal study results, together with several distances and angles useful for locating the AEA, are presented in this study.
Results: There were 13 main articles that analysed a total of 1388 AEA. It was absent from 2% to 14%. It was identifiable in computed tomography (CT) between 95% and 100%. It was located between the second and third ethmoidal lamella in 74.2% and at the skull base level in 66.6%. Ethmoidal sinuses pneumatisation was related to AEA location at the skull base. Between 83% and 85.3%, it was found at the suprabullar recess.
Conclusions: CT is useful for presurgery planning. AEA are more frequent between the second and third lamella and at skull level. Ethmoidal pneumatisation and Keros grades could be predictive factors for AEA relationship with the skull base level. The AEA, the axilla of the middle turbinate and the superomedial edge of the nose are in a straight line, being a simple and useful reference in endoscopic sinus surgery.

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PALABRAS CLAVE
Arteria etmoidal anterior;
Techo etmoidal;
Cirugía sinusal

La arteria etmoidal anterior en el laberinto etmoidal: Revisión bibliográfica sobre variantes anatómicas y referencias para la cirugía endoscópica

Resumen
Introducción: La arteria etmoidal anterior presenta muchas variaciones anatómicas en su trayecto. Tampoco existen referencias claras para localizarla, por esto, es fácil producir una lesión iatrógena. El objetivo de este trabajo es realizar una búsqueda bibliográfica para analizar las variantes y referencias endoscópicas reseñadas en la literatura científica para localizarla.
Material y métodos: Se ha realizado una revisión en la base de datos Medline y Embase, buscando tanto trabajos anatómicos como radiológicos. Tras la revisión se recogen los resultados de los principales estudios.
Resultados: Se recogen 13 estudios que analizan en total 1.388 arterias etmoidales anteriores. Se encuentra ausente entre un 2-14%. Es identificable entre un 95-100% en una TC. Se sitúa entre la 2.ª y la 3.ª lamela etmoidal en un 74,2% y a nivel basicraneal en un 66,6%. La neumatización etmoidal se relaciona con la situación de la arteria etmoidal anterior a nivel de la base de cráneo. Entre el 83-85,3% se localiza a nivel del receso suprabullar. Se exponen varias distancias y ángulos medidos para poder localizarla.
Conclusiones: La TC es útil para una planificación prequirúrgica. Se localiza más frecuentemente entre la 2.ª y 3.ª lamela etmoidal y a nivel basicraneal. Factores como la neumatización etmoidal o el grado de Keros pueden predecir su relación con el nivel basicraneal. La arteria etmoidal anterior, la axila del cornete medio y el borde superomedial de la nariz forman una línea recta, siendo una referencia sencilla y útil en la cirugía endoscópica.

Introduction

Currently, endoscopic sinus surgery has been incorporated into the routine of ENT services. The advantages offered by endoscopy are indisputable; however, to approach the surgery successfully, it is essential to have anatomical knowledge of the structures in the area and the endoscopic landmarks to be aware of the surgical field.

Locating the anterior ethmoidal artery (AEA) is particularly complicated, as it presents great anatomical variability and unusual anatomy features, since it is present in the nostrils, at the intracranial level on the bottom of the skull base and at the intraorbital level. A brief reminder of AEA anatomy: It originates from the ophthalmic artery, at the intraorbital level. It is situated between the superior oblique and the medial rectus muscles, entering by the anterior ethmoidal foramen (AEF) into the anterior ethmoidal canal (AEC). At the exit of the canal, it is situated on the cribriform plate giving the anterior meningeal branch. It continues in an anterior direction, entering the nasal cavity through the anterior ethmoidal orifice of the cribriform plate, where it branches.

There is no consensus in the literature on which landmarks are the most useful in locating it, because the different works existing analyse different references, and mixed results are published in terms of anatomy.

The purpose of this study was to carry out a review of the literature by collecting the most important works, so as to analyse the variations and anatomical references that are considered most useful for identifying the AEA in sinonasal endoscopy.

Material and methods

We carried out a non-systematic review using the Medline database, seeking first the *Medical Subject Heading (MeSH)* descriptor of *anterior ethmoidal artery*. Since it did not exist, we conducted a search using the terms *"anterior ethmoidal artery"*, *"anterior ethmoid artery"*, *"anterior ethmoidal canal"*, *"anterior ethmoid canal"*, *"ethmoidal roof"*, *"ethmoid roof"*, and *"sinus surgery"* without using any kind of limitations. The combination of these keywords and the resulting number of items are detailed in the following search pattern:

	No. of articles
#13 Search (#7) AND (#12)	114
#12 Search (#10) OR (#11)	35,395
#11 Search sinus surgery	35,333
#10 Search #8 or #9	176
#9 Search ethmoidal roof	62
#8 Search ethmoid roof	154
#7 Search #3 OR #6	260
#6 Search #4 OR #5	60
#5 Search anterior ethmoid canal	45
#4 Search anterior ethmoidal canal	36
#3 Search #1 or #2	232
#2 Search anterior ethmoid artery	125
#1 Search anterior ethmoidal artery	169

We analysed the abstracts of the 114 final articles resulting from the search. Of these, we selected 45, which were studied. Finally, we included data from 13 main articles, by relevance and importance in the field.

The search was broadened in the *Biblioteca Cochrane plus* library and the *Embase* database with the previous keywords, but no additional articles relevant to the topic were obtained. We also used the *Google académico (Google Scholar)* search engine to broaden the search, with the previous keywords, including one article in our study.[11]

Results

After reviewing the articles, we collected data from the 13 main studies, selected as the most important due to their contribution of data on the AEA and its location. Given the study material, these articles could be divided into various categories (Table 1). Three studies were based on anatomical dissections on cadavers (Araujo,[1] Erdogmus,[2] Lee[3]). One author conducted his study on patients who required surgery on the area (Hemmaoui[4]). Five carried out a radiological computed tomography (CT) study and subsequently dissected cadavers (Floreani,[5] Han,[6] Lannoy,[7] Moon,[8] Simmen[9]). Finally, four other researchers carried out their work through only radiological CT observations (Basak,[10] Gonzalez,[11] McDonald,[12] Souza[13]). Adding the different articles, the number of AEA studied in dissection works reached 430, and in radiology studies, 958. In total, considering all the articles, there were 1,388 AEA studied.

The artery originated in 100% of cases from the ophthalmic artery.[2] The diameter of the AEA had an average of 0.92±0.2 mm on the right and 0.88±0.15 mm on the left. The average length at the intranasal level was of 5.82±1.41 mm.[1]

As for its absence, Han[6] found bilateral absence together with the vein and the nerve in one specimen (2/48; 4.2%), and Erdogmus[2] also found one bilateral absence (2/38; 5.3%). Lang[14] reported a rate of bilateral absence of 2% and unilateral of 14% and Kirchner[15] an absence of 9%.

Table 1 Description of the main studies selected

Author	Type of study	No. of cases
Araujo	Cadaver	50
Basak	CT	222
Erdogmus	Cadaver	38
Floreani	Cadaver+CT	48
González	CT	240
Han	Cadaver+CT	48
Hemmaoui	Surgical patients	68
Lannoy	Cadaver+CT	18
Lee	Cadaver	56
McDonald	CT	100
Moon	Cadaver+CT	70
Simmen	Cadaver+CT	34
Souza	CT	396

CT indicates computed tomography.

Another aspect would be the identification of the artery during surgery; Hemmaoui[4] identified it in 60 of 68 cases. In radiology, sinus CT scans, Basak[10] identified it in 82% and put the figure of absences at 13%, with 3% indeterminate results. McDonald[12] identified it in only 33%, although the AEF was identified through imaging studies in 95% on a bilateral basis, concluding that this structure was valid for locating the AEA. We should clarify that the AEF corresponds to the orbital orifice of the AEC (Figure 1).

Souza[13] studied the identification of the ethmoidal canal or of anatomical landmarks that served to locate it in coronal CT scans. These were the AEF and the anterior ethmoidal groove on the lateral wall of the olfactory fossa. The canal was identified directly in only 41% of cases. However, the AEF was identified in 100% of the observations and the anterior ethmoidal groove was located in 98%, reinforcing the fact

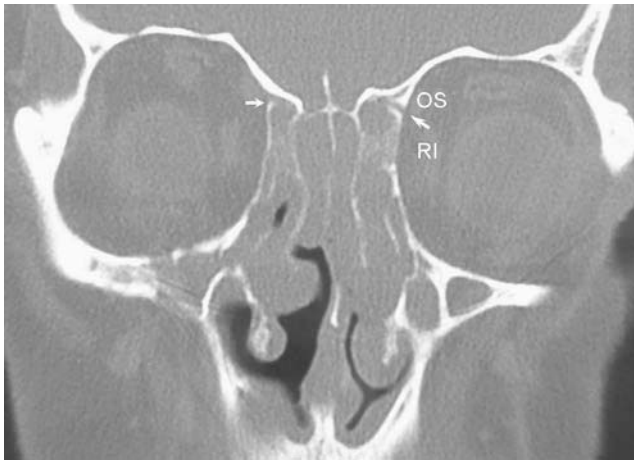

Figure 1 Coronal CT of paranasal sinuses showing the anterior ethmoidal foramen (arrows) and anterior ethmoidal canals. OS indicates superior oblique; RI, medial rectus.

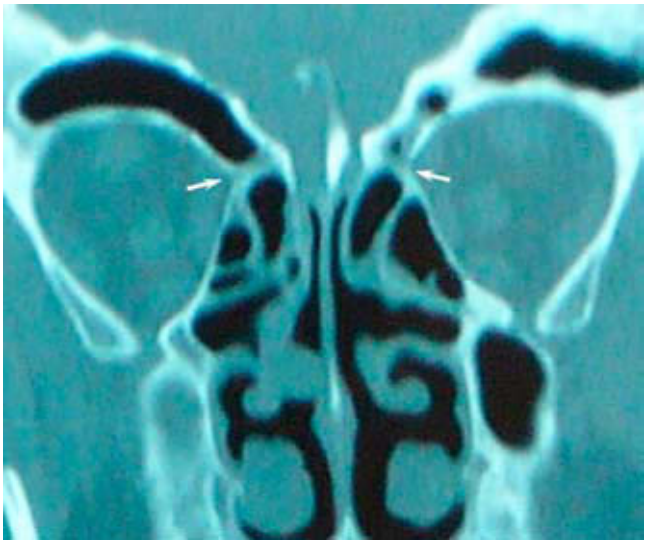

Figure 2 Coronal CT scan with a large supraorbital cell and the anterior ethmoidal canal (arrow) below the level of the skull base.

that these structures were easily identifiable and valid for locating the AEA. There was also a statistically significant relationship between the existence of supraorbital pneumatization and AEC observation (Figures 2-3).

Several authors observed cases in which the AEC was not continuous in its bone structure, but instead presented partial or total dehiscence. The rate was variable according to the author. Simmen[9] reported a rate of 5.9%, Moon[8] of 11.45%, Floreani[5] of 16% and Araujo[1] of 66.7%.

Four authors[2,6,8,9] referred to AEA location with respect to the ethmoidal lamellae (Table 2). Grouping the data, the AEA was placed at the level of the second lamella in 3 cases; between the 2nd and 3rd in 138 (74.20%), with this localisation being the most common by far; in the 3rd in 30 (16.13%); and after the 3rd in 15 cases (8.06%).

Seven authors analysed the relationship of the AEA with the skull base, with a total of 542 AEA analysed. It was located at the level of the skull base in 361 cases (66.6%) and below the level of the skull base in 181 (34.4%) (Table 3).

Three authors measured the distance from the AEA to the skull base in cases in which it was located below it. For Han,[6] it was located approximately at just 1 mm, while Simmen[9] set the distance at between 3-5 mm. Araujo[1] made a division into 2 sections: between 2-5 mm, in 2 cases of 8, and at more than 5 mm in 6 cases from 8. Floreani[5] separated his cases according to the Keros classification. He noted that, in cases with Keros grades II and III, the AEA was below the level of the base with a bony mesentery.

Two authors analysed the influence of supraorbital pneumatization and the level at which the AEA was located with respect to the skull. Simmen[9] correlated pneumatization of supraorbital and ethmoid cells with the location of the AEA at the level of the skull base. In the 10 cases with large supraorbital cell and considerable pneumatization, the AEA was located 3.7 mm below the level of the skull base on average (range 1-8 mm). In 6 cases, there was a small cell with less pneumatization, and the AEA was located at 0.2 mm from the skull base on average (range 0-1 mm). In 17 of 18 cases without supraorbital cell and poor pneumatization, the AEA was at the level of the skull base. Souza[13] reported that there was supraorbital pneumatization in 35% of cases, and that in these cases the AEA ran below the level of the skull base, away from the ethmoid roof but without specifying the distance.

Other authors referred to relations of the AEA with structures identified by endoscopy, which could make it easier to locate. Hemmaoui[4] related it to the ostium of the frontal sinus. In his series, the frontal sinus ostium was separated from the AEA by just one ethmoid cell in 66%, by 2 cells in 16% and by 3 in 1%. In 4% of cases, there was no separation; in these cases, the AEA was located in

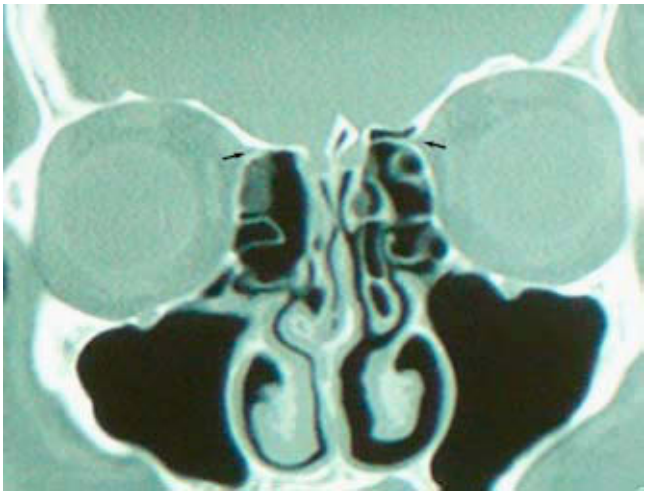

Figure 3 Coronal CT scan with absence of supraorbital cell and displaying the anterior ethmoidal canal.

Table 3 Relationship of the AEA with the level of the skull base

Author	Cases	At the level of the base		Below the base	
		No. of cases	%	No. of cases	%
Simmen	34	22	64.7	12	35.3
Moon	70	60	85.7	10	14.3
McDonald	100	72	72	28	28
Lannoy-Penisson	18	8	45	10	55
Floreani	48	31	64	17	36
Araujo	50	42	83.36	8	16.64
Basak	222	126	57	96	43
Total	542	361	66.6	181	33.4

Table 2 Relationship of the AEA with the ethmoidal lamellae

Author	Cases	In the 2nd		Between 2nd-3rd		In the 3rd		Behind the 3rd	
		No. of cases	%	No. of cases	%	No. of cases	%	No. of cases	%
Han	46			14	31	17	36	15	33
Simmen	34			34	100				
Erdogmus	36	2	5.26	29	76.32	5	18.32		
Moon	70	1	1.42	61	87.15	8	11.43		
Total	186	3	1.61	138	74.20	30	16.13	15	8.06

Table 4 Useful distances for locating the anterior ethmoidal artery

Distance	Author	Figure, mm
Limen nasi – AEC	Moon	49±4.9
	Erdogmus	48.1±3.2
Anterior nasal spine – AEC	Moon	53.6±4.9
	Araujo	61.72±4.18
Axilla of the middle turbinate – AEA	Han	17.5
	Lee	20 (17-25)
	Araujo	21.14±3.25
Superomedial edge of nose – AEA	Lee	62 (55-75)
	Araujo	64.04±4.69

AEA indicates anterior ethmoidal artery; AEC, anterior ethmoidal canal.

Table 5 Measurements of angles with respect to the anterior ethmoidal canal

Angle	AEC
Horizontal plane passing through the limen nasi	Moon: 54.5±6.8
Horizontal plane passing through the anterior nasal spine	Moon: 51.4±6.4

AEC indicates anterior ethmoidal canal.

the posterior wall of the frontal sinus ostium. There was bilateral symmetry in 67% of cases.

Simmen[9] and Erdogmus[2] analysed AEA location with respect to the ethmoid bulla, locating it in 85.3 to 83%, respectively, at the level of the suprabullar recess. According to Simmen, it was located in 5.9% in the top of the bulla and in 8.8% in the retrobullar recess.[9]

In another aspect, there were many authors who calculated distances and angles with reference to the AEA or AEC with respect to different points to try to find useful information for locating the AEA in endoscopic surgery. However, only some of them had been measured by more than one author, and it was difficult to draw comparisons. We collected those that had been studied by several authors, and that we believe to be the most relevant (Tables 4-5).

Discussion

The AEA arises at the intraorbital level, in the medial side of the ophthalmic artery,[2,16] which in turn is a branch of the internal carotid artery. It then runs through the AEC in the thickness of the ethmoid; this channel is perpendicular to the plane of the nasal septum with a direction going from posterolateral to anteromedial.[8] It leaves the canal at the intracranial level in the skull base above the cribriform plate. Finally, it crosses this through the anterior ethmoidal orifice, ending in the nasal fossa and dividing into multiple branches.

Two authors[2,6] among those selected found absence of the AEA in 2 cadavers, having a significantly lower rate, 4.2% and 5.3%, compared to other studies (14%[14] and 9%[15]).

It is necessary to know the location of this artery to avoid causing damage during endoscopic sinus surgery. Therefore, knowing its location in anatomical studies can greatly help in identifying it. Its relationship with the ethmoidal lamellae is of special interest. We believe that a precise definition of this term is necessary, since it is given different meanings in different works.[9] The lamellae are vertical bony structures that make up and compartmentalise the ethmoidal labyrinthine complex[11] and are relatively constant. The 1st lamella corresponds to the uncinate process, the 2nd to the ethmoid bulla and the 3rd would be the basal lamina of the middle turbinate, which divides the anterior and posterior ethmoid. The 4th corresponds to the layer of the superior turbinate, and the 5th lamella, which is variable, would correspond to the lamina of the superior turbinate[9,11] (Figure 4).

After analysing the studies, all the authors except Han[6] place the AEA more frequently between the 2nd and 3rd lamella, with a rate range of 100%-31%. Han[6] explains that he has very few cases in his study and this is probably the reason why his results are mixed; however, the number of cases is similar to or even more than to other studies. In most of the articles, the AEA is located more commonly among the 2nd and 3rd lamellae, that is, between the anterior wall of the bulla and the insertion of the basal lamina of the middle turbinate. Therefore, the fact that the AEA predominates in the 3rd lamella in the work of Han[6] may be due to methodological, racial or conceptual differences.

The relationship with the skull base is important, because the chances of injury during surgery are higher if the AEA is below the skull base. All the authors except one (Lannoy[7]) most commonly locate it at the base of the skull, with rates ranging from 57%[10] to 85.7%[8]. The rate of Lannoy[7] is of 45%, somewhat mixed. This may be because it is the study

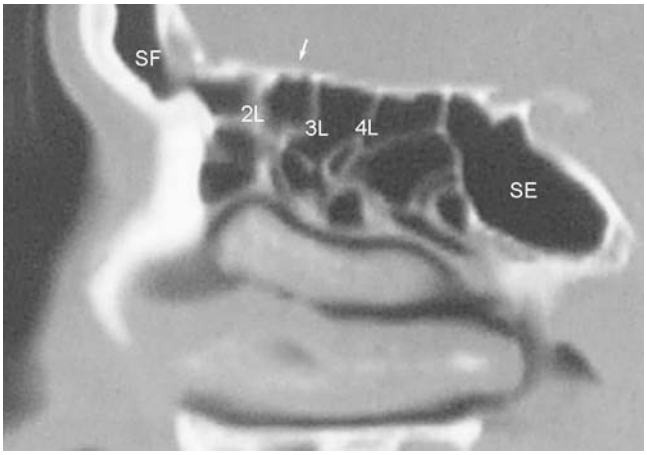

Figure 4 Sagittal CT showing the anterior ethmoidal canal (arrow) and ethmoidal lamellae. SF: frontal sinus; 2L: second lamella; 3L: third lamella; 4L: fourth lamella; SE: sphenoid sinus.

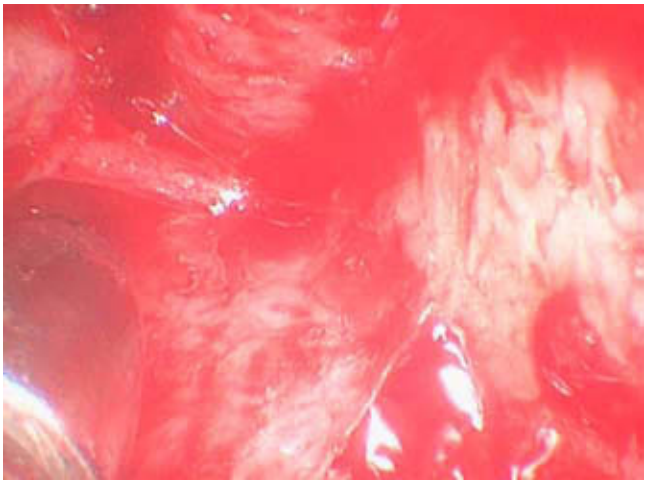

Figure 5 View of the anterior ethmoidal artery in endoscopic sinus surgery.

with the fewest cases, only analysing 18 AEA. In view of the results, we find that it is more common for the AEA to traverse the width of the ethmoid at the level of the skull base than beneath it. However, it should be borne in mind that, although we considered the highest rate (85.7%[8]), the AEA passed below the level of the skull base in a percentage that is not negligible.

As described by several authors, a preoperative coronal CT enables identification of the AEA, making it a very useful technique that helps in surgery planning. While identifying the AEC in its entirety is difficult (McDonald,[12] 33%; Souza,[13] 41%), it can be located through other, easily identifiable references such as the AEF (McDonald,[12] 95%; Souza,[13] 100%; Gotwald,[17] 95%) or the anterior ethmoidal groove (Souza,[13] 98%; Gotwald,[17] 84%).

Finding a correlation between the height at which the AEA is located with any anatomical or radiological feature would be very useful in the planning of surgery. Floreani[5] finds that if the patient has a Keros grade II or III, the AEA is below the level of the skull base. It should be remembered that the Keros classification[18] refers to the configuration of the ethmoid roof according to the length of the lateral lamina. In grade I, this lamina (measured from the ethmoid roof to the cribriform plate) measures between 0-3 mm; in grade II, between 4-7 mm; and in grade III, between 8-16 mm.

The pneumatization of the ethmoid sinuses and the existence of a supraorbital cell, which is found in a variable percentage (Chung,[19] 26%; Simmen,[9] 47.06%; Souza,[13] 35%) are factors that would influence[9,13] the level of the AEA. Simmen[9] concludes that the degree of pneumatization of the ethmoid cells and the presence or absence of a supraorbital cell could be used as predictive factors for locating the AEA in relation with the level of the skull base. In patients with a large supraorbital cell and good ethmoid pneumatization, it must be assumed that the AEA is below the base of the skull. If there is no supraorbital cell and pneumatization is poor, it is likely that the AEA is at the level of the base. Souza,[13] like Simmen,[9] notes an association between the presence of this supraorbital cell and the location of the AEA below the ethmoid roof.

Several authors[1,5,8,9] have found that, in cases where the AEA runs below the level of the skull base, it is included in a bony mesentery of variable dimensions that would join it to the ethmoid roof. This structure could be mistaken, leading to AEA injury, so this anatomical variant must also be contemplated. Varying rates of bone dehiscence of the canal are also reflected, between 5.9% (Simmen[9]) and 66.7% (Araujo[1]). This could be due, as Moon[8] concluded, to racial differences or to counting the sites where the ethmoidal nerve or vein pass through the canal.

Regarding methods for locating the AEA, there are many authors who carry out measurements by observing anatomical landmarks. There is a wide dispersion of measurements, as each author selects his or her particular references (Figure 5).

Lee[3] suggests using the axilla of the middle turbinate and the superomedial edge of the nose as references, because they are easily identifiable points. Both Lee[1] and Erdogmus[2] find that these two points and the AEA form a straight line. Therefore, with a 0º endoscope, there would be no problems in following this theoretical line and finding the AEA.

However, Araujo[1] criticises this hypothesis because, in his study, the straight line which passes through the superomedial edge of the nose and the axilla of the middle turbinate crosses some 3-4 mm posterior to the AEA. This might be because Lee[3] performs a resection of the mucosa of the axilla of the middle turbinate, obtaining a more anterior measurement. Three authors measure the distance between the AEA and the axilla of the middle turbinate, obtaining similar average distances: Han[6] 17.5 mm, Lee[3] 20 mm, Araujo[1] 21.14 mm. However, the ranges are wide, going from 17 to 25 mm, which illustrates interindividual variability. Despite this, we believe that this measurement based on these references may be the most useful, as they are easily identifiable in routine surgery, and provide a fairly accurate location.

Conclusions

1. The identification of AEA and/or AEF is possible in almost all cases in a coronal bone CT with thin sections; we therefore recommend the implementation of this technique in ethmoid area surgery.
2. The AEA is found most frequently between the 2nd and 3rd ethmoidal lamellae and at the level of the skull base.
3. The AEC presents bone dehiscence in a variable percentage.
4. Factors such as a marked ethmoid pneumatization, the existence of a supraorbital cell or Keros grade II or III are predictors of an AEA location below the level of the skull base, therefore indicating a greater risk of injury.
5. The superomedial edge of the nose and the axilla of the middle turbinate form a straight line with the AEA, this reference being valid for its location.

Conflict of interests

The authors declare no conflict of interests.

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