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Original Research Article

Relationship of anterior ethmoidal artery with skull base and posterior wall of frontal sinus: a computed tomography-based retrospective clinical study

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ABSTRACT

Background: The close proximity of anterior ethmoidal artery (AEA) to the skull base predisposes the artery to injury during ESS. This study aims to decipher the course of AEA and determine its relationship with the skull base and posterior wall of frontal sinus with the help of computed tomography.
Methods: The vertical distance between the skull base and the anterior ethmoidal foramen in the coronal scans, the horizontal distance between posterior wall of frontal sinus ostium and AEA in the sagittal scans and the number of intervening cells between posterior wall of frontal sinus and AEA were analyzed in CT scans of 75 patients over a period of six months.
Results: The AEA was lying 2.5-5 cm below the level of skull base in majority of the CT scans analyzed. Most of the CT scans studied demonstrated only a single intervening cell between posterior wall of frontal sinus ostium and AEA on either side. In our study there was a strong positive relationship between the AEA- skull base distance and between the AEA-posterior wall of frontal sinus distance on either side.
Conclusions: Distance between the AEA and skull base is variable, but a freely running AEA within a bony canal was a more common variant than skull base variant in our study. AEA-skull base distance and AEA-frontal sinus distance on right side correlated with values of left side indicating symmetrical course of the AEA on either side in an individual.

Keywords: AEA, Skull base, Posterior wall of frontal sinus, Suprabullar recess

INTRODUCTION

The anterior ethmoidal artery (AEA) originates from the ophthalmic artery in the orbit. It passes between the superior oblique and medial rectus muscles before leaving the orbit via the anterior ethmoidal foramen (situated in the fronto-ethmoidal suture). The anterior ethmoidal foramen leads to the anterior ethmoidal canal, which transmits the artery through the anterior ethmoidal sinuses. The relationship between the AEA and the skull base is intimate as the artery traverses the ethmoid bone along a significant portion of the skull base.[1] The AEA exits through the lateral lamella of cribriform plate and is most susceptible to injury at this site

Pennison et al observed three anatomical variations of AEA[2]: Type A represents an artery that is embedded in the skull base, type B represents the AEA running very close to the skull base presenting as a bony protrusion along the skull base and type C AEA courses freely within the ethmoid air cells being connected to the base of the skull by a thin bony mesentery.

The anatomical relationship between the AEA, skull base and frontal sinus is highly intricate and significant in various surgical procedures such as functional endoscopic sinus surgery, endoscopic surgery of sinonasal tumors and skull base surgery.

Intraoperatively in such clinical scenarios, meticulous attention needs to be paid to the AEA's trajectory, as damage to this artery either within the intact bony canal wall or over the sites of exposure within its incomplete canal wall, can result in significant complications such as retrobulbar hematoma, cerebrospinal fluid leak, or meningitis.[3]

High-resolution coronal CT images are particularly useful for evaluating the entire trajectory of AEA and its anatomical relationship with the anterior skull base.

In this study we aim to decipher the course of AEA with the help of computed tomography and determine its anatomical relationship with the skull base and the posterior wall of frontal sinus, as pre-operative 3D orientation of AEA within the ethmoidal complex can increase the preparedness during ESS.

METHODS

This retrospective cross -sectional study was done using computed tomography images of 75 patients treated in ACS medical college and hospital, Vellapanchavadi, Chennai during six months' time period (January to June 2024). CT scans of individuals aged under 18 years of age were excluded from our study due to the probable underdevelopment of the nasal skeleton. Patients who had previously undergone sinus surgeries were also excluded from our study. All CT scans were performed using one standardized protocol (KVP 130, 84 mAs, FOV200, Window level-OSTEO, and 1.0 mm contiguous axial slice) by experienced CT technicians.

One millimeter thick sagittal and coronal images were acquired through sequential reconstruction of axial images. In the Sagittal plane, the AEA canal appears as a round structure (end on) in the roof of the ethmoid sinuses. But in coronal and axial planes, the AEA canal appears as a tubular structure with oblique course in the roof of anterior ethmoid sinuses, identification of the AEA canal in the sagittal plane was guided by its identification in coronal and axial planes and then drawing corresponding reference lines.

In our study the vertical distance between the skull base and the anterior ethmoidal foramen was measured in the coronal scans (Figure 1) and horizontal distance between posterior wall of frontal sinus ostium and AEA was measured in the sagittal scans (Figure 2). The data thus obtained was analysed using SPSS version 26 using appropriate statistical measures.

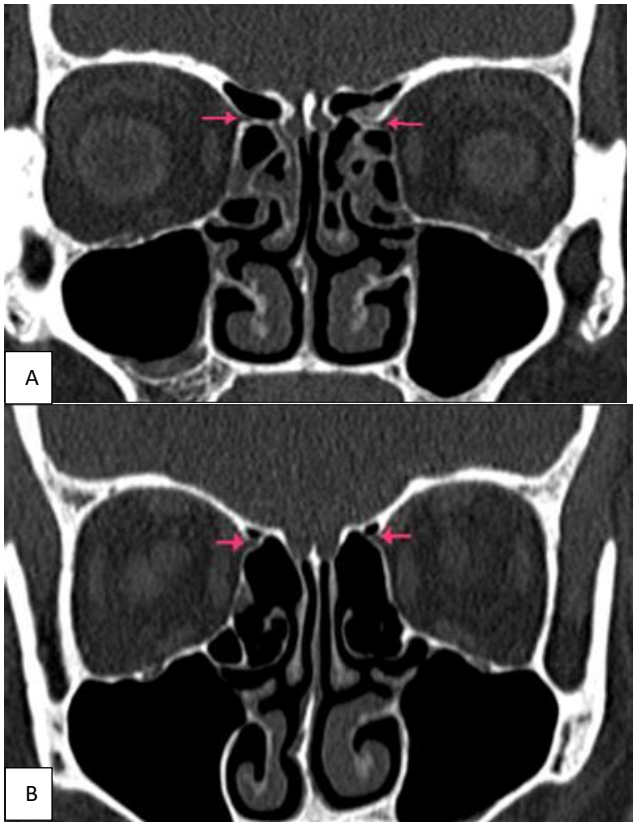

Figure 1 (A and B): Bony notch (arrow) depicts the anterior ethmoidal foramen. Coronal CT images in two different cases. AEA coursing freely and AEA coursing at the level of skull base.

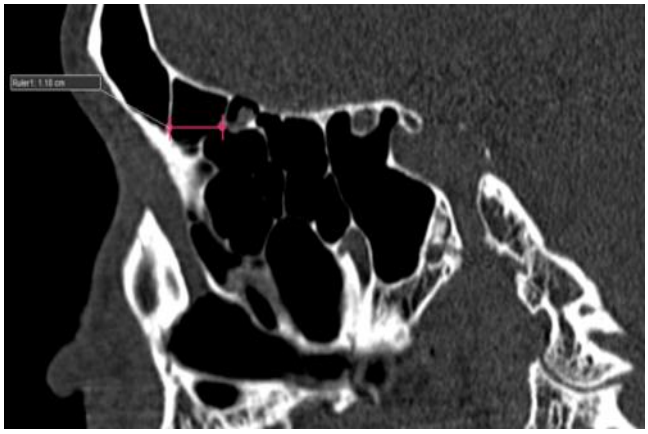

Figure 2: Sagittal CT showing distance between AEA and posterior wall of frontal sinus ostium.

RESULTS

Out of the CT images of 75 subjects which met the study, 33 scans belonged to male subjects and the rest 42 belonged to female subjects. The mean age of the individuals whose CT images were analysed in our study was 41±15 years (Range-19 to 82 years).

The mean distance between AEA and skull base on right side was 4.36±0.99 mm, whereas that on the left side was 4.40±1.107 mm.

The mean distance between AEA and posterior wall of frontal sinus on the right side was 12.30±4.020 mm and that on the left side was 12.16±2.15 mm.

No significant association was observed between age and gender of an individual and course of AEA (Table 1).

In our study, the AEA was lying 2.5-5 cm below the level of skull base in 69.3% of the CT scans on right side and 74.7% of CT scans on left side (Table 2).

Significant correlation was noticed on comparing the height of AEA-from the Skull base of right and left sides. (r (75)=0.543, p<0.001) (Figure 3).

Results of the Pearson's correlation test indicated a significant large positive relationship between AEA-skull base distance on right and left sides (r (75)=0.543, p<0.001).

Most of the CT scans studied demonstrated only a single intervening cell between posterior wall of frontal sinus ostium and AEA on either side (Table 3).

Pearson's correlation test also indicated a significantly positive relationship between the distance of AEA from the posterior border of frontal sinus on right and left sides. (r(75)=0.73, p<0.001) (Figure 4).

Results of the Pearson's correlation test indicated a significant large positive relationship between AEA-Frontal sinus distance on either side (r(75)=0.73, p<0.001).

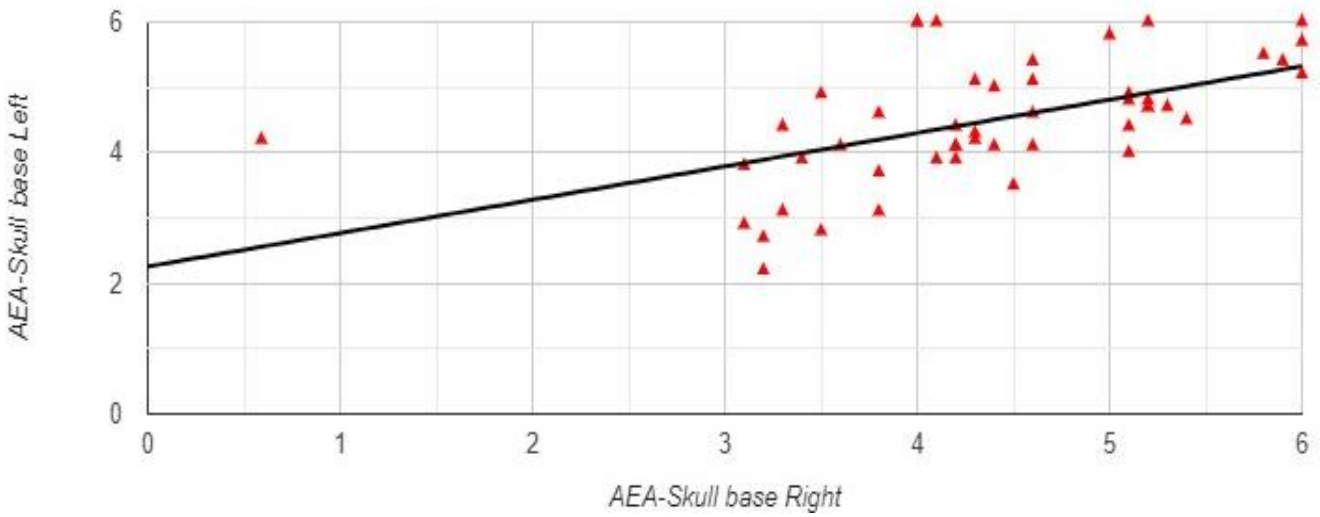

Figure 3: Correlation between AEA-skull base distance on right and left sides.

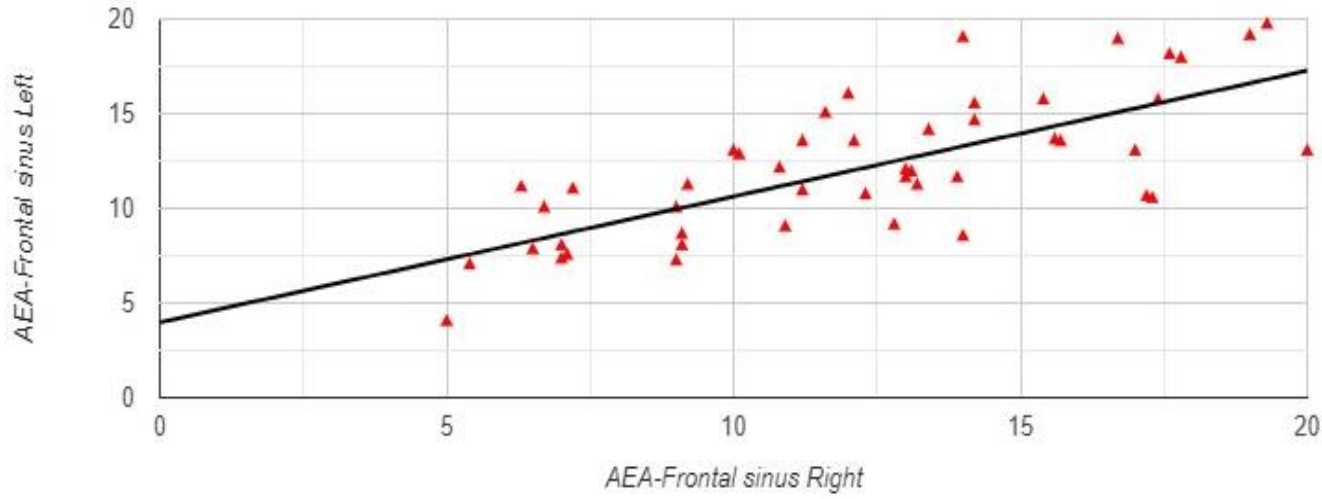

Figure 4: Correlation between AEA-frontal sinus distance on right and left sides.

Table 1: Association between age and gender and course of AEA.

Socio-demographic variables	Distance (in mm) between AEA and Skull base right (Mean±SD)	P value	Distance (in mm) between AEA and skull base left (Mean±SD)	P value	Distance (in mm) between AEA and frontal sinus right (Mean±SD)	P value	Distance (in mm) between AEA and Frontal sinus left (Mean±SD)	P value
Age (in years)								
≤41	4.33±1.15	0.450	4.61±1.29	0.081	11.64±4.16	0.546	11.42±3.47	0.494
>42	4.39±0.822		4.17±0.820		13.02±3.82		12.96±3.75	
Sex								
Male	4.20±1.22	0.236	4.35±1.31	0.332	11.46±3.75	0.653	11.78±3.57	0.726
Female	4.48±0.78		4.45±0.95		12.96±2.95		12.46±3.76	

Table 2: Distance between AEA and skull base on either side.

Distance between anterior ethmoidal artery to skull base	Right side N (%)	Left side N (%)	Both sides put together (%)
<2.5 mm	3 (4)	2 (2.7)	3.33
2.5-5 mm	52 (69.3)	56 (74.7)	65.34
>5 mm	20 (26.7)	17 (22.6)	31.33
Total	75	75	100

Table 3: Number of intervening air cells between AEA and posterior wall of frontal sinus in right and left side.

No. of intervening air cells	Right	Percentages (%)	Left	Percentages (%)
0	10	13.3	9	12
1	48	64	51	68
2	17	22.6	14	18.6
3	0	0	1	1.3

DISCUSSION

The anterior ethmoidal artery traverses from the orbit to the cranial cavity through the orbitocranial canal. The lateral end of the orbitocranial canal is at the suture line of the frontal bone and the lamina papyracea. The medial end of the canal at the cribriform plate is the thinnest part of the anterior cranial fossa. The orbitocranial canal may have bony dehiscence (40%), which leave the anterior ethmoidal artery exposed to the risk of trauma. The course of the anterior ethmoidal artery within its canal in the ethmoid sinus is highly variable.[4] Computed tomography-guided evaluation in all planes orients a surgeon about the probable location, course, and relations of AEA preoperatively.

The artery is more prone to injury when it is coursing freely in the orbitocranial canal, especially in patients who have long lateral lamellae of the cribriform plate with deep olfactory fossae (Keros type 3).[5] In our study, the mean distance between AEA and skull base was 4.350±1.042 mm. In our study, the freely traversing variant of AEA was much more common (96.67%) (Figure 1 A) than skull the base variant (3.33%) (Figure 1 B).

Similar observations were made by Ko et al, Cankal et al and Joshi et al, in their studies. On the contrary, as per the studies done by Elizabieta et al, Simmen et al, Yang et al and Moon et al, the skull base variant of AEA was the most common one (Table 4).[6-11]

During frontal sinus clearance, there is a fear of injuring AEA since it forms the posterior boundary of the frontal sinus. The radiological assessment of distance between AEA and frontal sinus ostium preoperatively helps to prevent injuring AEA during frontal sinus surgery.

Since frontal recess is a wide area, it might be more accurate to measure distance specifically from posterior wall of frontal sinus ostium (Figure 2). Waheed et al have also used the posterior wall of frontal sinus ostium as landmark for measuring the distance between AEA and frontal sinus.[13] But, other articles do not specify any such landmarks to ensure standardized measurements.

As per our study, the mean distance between the posterior wall of the frontal sinus ostium and anterior ethmoidal artery was 12.15±3.72 mm, which was slightly higher than the values as per the studies done by Ko et al and Waheed et al (Table 5).[6,13]

Table 4: Data from literature review on distance between AEA and Skull base.

Authors	Total no. of CT images/ cadavers analyzed	% of cases AEA was running at the level skull base/ close	% of cases where AEA coursed freely	% of cases where AEA was less than 2.5 mm	% of cases where AEA was between 2.5-5mm	% of cases where AEA was >5 mm	Mean distance between AEA and skull base on either side
Waheed et al[13]	144	64.6%	35.4%	64.6%	22.2%	13.3%	
Simmen et al[10]	44	64.7%	35.3%				
Filho et al[14]	25 (cadavers)	83.3%	16.6%	83.3%	4.1%	12.5%	
Yang et al[11]	30	83.3%	16.7%				
Moon et al[12]	70 (cadavers)	85.71%	14.28%	93.44%	6.55%		
Ko et al[6]	144	16%	84%				1.65±1.90 mm
Cankal et al[7]	150	16%	84%				
Joshi et al[8]	100	20%	80%	14%	86 %		
Present study (2024)	75	3.33%	96.67%	3.33%	65.34%	31.33%	4.350±1.042 mm

Table 5: Data from literature review on distance between AEA and Posterior wall of frontal sinus.

Authors	Total no. of CT images analyzed	Mean distance b/w AEA and posterior wall of frontal sinus right side	Mean distance b/w AEA and posterior wall of frontal sinus left side	Mean distance b/w AEA and posterior wall of frontal sinus (R and L together)
Ko et al[6]	75	-	-	8.58±5.56 mm (0-22.6 mm)
Waheed et al[13]	150	9.13±5.02 mm	9.21±4.47mm	9.17±4.72 mm
Notaris et al	6	-	-	10.916±1.386 mm
Simmen et al[10]	34	-	-	11 mm (6-15 mm)
Present study (2024)	75	12.120±3.905 mm	12.188±3.561 mm	12.15±3.72 mm

Table 6: Types of AEA in relation to posterior wall of frontal sinus

Distance of AEA from frontal sinus ostium	Type 1 (0-5 mm) N (%)	Type 2 (5-10 mm) N (%)	Type 3 (10-15 mm) N (%)	Type 4 (>15 mm) N (%)
Present study (total n=150)	3 (2)	40 (26.6)	71 (47.3)	36 (24)
Waheed et al[13] (total n=144)	25 (17.4)	60 (41.7)	46 (31.9)	13 (9)

On assessment of distance between AEA and posterior wall of frontal sinus, type 3 (10-15 mm) was found to be the commonest pattern noted in the present study, but according to Waheed et al type 2 (5-10 mm) pattern was the commonest one (Table 6).[13]

In our study there was a strong positive relationship between the AEA- skull base distance on either side (Figure 3). Similarly, there was also a strong positive relationship between the AEA-posterior wall of frontal sinus distance on either side (Figure 4). Even in the study done by Filho et al on nasal fossae of 25 cadavers, there was no significant statistical difference between skull base-AEA distance on right and left sides.[14]

Various studies have been done on cadavers for analysing the intranasal course of AEA. Measurements made from external landmarks such as the junction of the medial and lateral crura of the lower lateral cartilages have been used to locate the AEA.[5] In addition, the distance of AEA from limen nasi, anterior end of the middle turbinate and lamina papyracea have also been analyzed in the past.[12] But none of these parameters have been that useful in guiding a surgeon while identifying the AEA during endoscopic sinus surgery.[10]

Gotwald et al in their study on plastinated cadaver specimens and coronal CT images of patients with sinusitis, found that the anterior ethmoidal artery coursed between superior oblique and medial rectus muscles in the eyeball and entered the ethmoidal labyrinth through the anterior ethmoidal foramen which was visible as a small indentation over the lamina papyracea.[15] As the artery traversed the lateral wall of fovea ethmoidalis, subtle thinning was noticed in the bony sulcus overlying the artery.

According to Simmen et al the commonest location of the artery was in suprabullar recess (83.3%).[10] In their study they observed that whenever a supraorbital cell was present, the AEA was frequently located just behind the supraorbital cell. Significant pneumatization with a large

supraorbital cell made AEA more susceptible as the artery could be coursing freely in such cases. When the roof of the ethmoidal bulla was attached to skull base, the AEA was seen as the next undulation in its roof.[10] Occasionally, it could be accessed directly through the space between the middle turbinate and medial wall of the bulla. Simmen et al additionally stated that after entering the ethmoid through the anterior ethmoidal foramen, the artery could most often be found travelling anteromedially in an oblique manner.

Cho et al reported that the frontal recess pneumatization patterns differ in the Asian and Caucasian adult populations.[16] Specifically, supraorbital ethmoid cells were found to be more common in Caucasians while suprabullar cell and terminal recesses were more common in Asians. Pneumatization patterns surrounding the frontal recess might have a significant effect on the relationship between the AEA and the frontal recess. In our study majority of the subjects had one intervening ethmoidal air cell on either side between frontal sinus ostium and anterior ethmoidal artery (64% and 68%) (Table 3).

The fear to handle disease surrounding AEA can be minimized by having detailed anatomical knowledge of the course of AEA along with regular preoperative radiological assessment of the AEA on HRCT PNS.

Limitation

The difference in the anatomical course of AEA between the present study and the older articles in literature could be attributed to the differences in the nature of selected sample, the retrospective nature of the study and the number of CT- scans rejected on account of poor image quality.

CONCLUSION

The distance between the AEA and skull base is variable but a freely running AEA within a bony canal was a more common variant than skull base variant in our study. The AEA- skull base distance and AEA-frontal sinus distance on right side correlated with the values of left aside indicating symmetrical course of AEA on either side in an individual.

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