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The Anatomical Relationship between the Anterior Ethmoid Artery, Frontal Sinus, and Intervening Air Cells; Can the Artery Be Useful Landmark?

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전두동에 대한 해부학적 표식자로서 전 사골동맥의 유용성

고영범 · 김명구 · 정용기

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Background and Objectives The anatomy surrounding the frontal sinus (FS) and the anterior ethmoid artery (AEA) is variable and complex. We tried to determine the value of AEA as a landmark for finding FS during endoscopic sinus surgery.
Subjects and Method Using the high-resolution CT scans of coronal and sagittal reconstruction, the distance between AEA and FS (D-AF) and the number and type of intervening cells between these two structures were investigated. Next, the distance between AEA and the anterior skull base (D-AS) was measured and the correlation between D-AF and D-AS was analyzed.
Results A total of 119 nasal cavities from 70 subjects was analyzed. Of these analyzed, AEA was located just behind the frontal recess in only 17 nasal cavities (14%) and one or two intervening cells were located between FS and AEA in the remaining 86% of the nasal cavities. The most frequent type of intervening cells was supra bullar cell, followed by supraorbital and frontal bullar cells. The mean D-AF and D-AS measurements were 8.58±5.56 mm (0−22.6 mm) and 1.65±1.90 mm (0−6.7 mm), respectively. D-AS was not significantly correlated with the distance between the FS and AEA (p=0.433), therefore, D-AS could not be predicted.
Conclusion The relationship between FS and AEA was non-predictable, and in most cases, there were one or two intervening cells between FS and AEA. Therefore a thorough review of thin section CT scans is necessary. Korean J Otorhinolaryngol-Head Neck Surg 2014;57(10):687-91

Key Words Computed tomography · Endoscope · Ethmoid · Frontal sinus · Paranasal sinus.

Introduction

The anterior ethmoid artery (AEA) is an important structure in functional endoscopic sinus surgery[1] and is regarded as a key landmark for surgical approaches to important anatomical structures, such as the frontal sinus and the anterior skull base.[2,3] In its course through the ethmoid cavity, the position and the course of the vessel is variable, therefore, classified into three subtypes: through the anterior part of the skull base bone, just inferior to the skull base, or away from the skull base in the ethmoid cavity.[4,5] For this reason, before performing surgery, surgeons must recognize these structural differences and relationships with surrounding structures, such as the skull base, frontal sinus, and orbit.[1]

The frontal sinus is the most challenging sinus for the endoscopic sinus surgeon due to its anatomical complexity and variability;[6,7] there are many studies reporting anatomical landmarks that may assist the surgeon in making a safe approach to the frontal sinus.[7-9] The AEA is known as a typical and classic landmark of the frontal sinus and there are several studies re-

porting that it lies just behind the frontal recess and can act as an anatomical landmark when approaching the frontal sinus.[4,10-15] However, the authors of this paper did not agree with applying this theory to all surgical cases due to the known anatomic variation of this area. For example, pneumatization patterns of the frontal sinus are diverse and various types of air cells may surround the frontal sinus, such as supra orbital, supra bullar, and frontal bullar cells. Additionally, the number and size of these surrounding cells is variable and the resultant diversity poses additional difficulties for understanding and utilizing anatomical relationships of the frontal sinus, AEA, and surrounding air cells during surgery. As a result, it may be difficult to apply a uniform anatomical relationship for these structures. Therefore, spatial understanding of this area is important and should be determined before endoscopic sinus surgery. Specifically, it is known that there are substantial differences in pneumatization patterns of surrounding cells and their frequency of detection between Caucasian and Asian subjects.[16] However, there are few studies that have focused on the anatomical relationship between the AEA, frontal sinus, and intervening cells in Asian patients, and there have been no trials to determine an appropriate anatomical predicting factor, such as the distance between AEA and anterior skull base and the characteristics of intervening cells, for anticipating the spatial relationship between the AEA and frontal sinus.

In this study, we examined the spatial relationship between the AEA and the frontal sinus as well as the utility of this artery for predicting the frontal sinus location in Asian patients. Additionally, the number and types of intervening ethmoidal air cells between these two structures, which have the potential to add complexity to the anatomy of this area, were also studied.

Subjects and Method

Study design and population

After this study was approved by the Institutional Ethics Committee, we retrospectively reviewed computed tomography (CT) images acquired from 157 patients who visited our institution with symptoms of rhinosinusitis between October 2009 and May 2011. For more accurate analysis of CT images, we applied the following exclusion criteria: 1) images of subjects under 18 years old to eliminate cases with potentially underdeveloped anatomy, 2) images showing evidence of an underdeveloped or absent frontal sinus, 3) images of subjects with a history of previous sinus surgery, and 4) subjects without sagittal reconstructed CT images.

Computed tomography protocol

All CT images were acquired using one standardized protocol (KVP 120, 100−170 mAS, FOV 125 mm, window level 2500, central level 250−500, and 1.0 mm contiguous axial slice) performed by experienced technicians. One-millimeter-thick sagittal and coronal images were acquired through sequential reconstruction of axial images. Two otolaryngologists (YG Jung and YB Ko) reviewed all images and attempted to come to a consensus on the anatomy. Cases of discordant opinions were excluded from further analysis.

Radiologic parameters

We attempted to identify the AEA on the reformed sagittal and coronal CT images. When the AEA was not identified, as on sagittal reconstruction images, no further measurements were performed and the images were excluded from further analysis. The AEA was categorized into three subtypes according to the relationship with anterior skull base (Fig. 1). The number of ethmoid air cells between the AEA and frontal sinus were compared among these three groups for finding any predictive factor. Then, we used tools on the picture archiving and communication system (PACS) to measure the vertical distance between the AEA and anterior skull base (D-AS) on coronal images and the horizontal distance between the AEA and posterior limit of the frontal recess (D-AF) on sagittal images (Fig. 2). All measurement was carried out at the mid-sagittal plane between the nasal septum and lamina papyracea. These images were then analyzed for the number and types of intervening cells between the AEA and frontal recess.

Definition of intervening ethmoid air cells

In order to define the relationship between the AEA and intervening ethmoidal air cells between the frontal sinus and AEA, we categorized ethmoidal cells located near the frontal recess as supraorbital cells, frontal bullar cells, and suprabul-

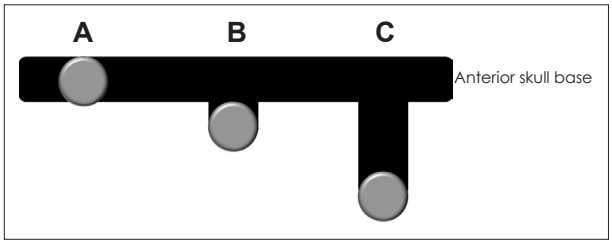

Fig. 1. The types of anterior ethmoid artery (AEA) according to the relationship with anterior skull base. Type A indicates the AEA which runs through skull base bone, type B indicates AEA having short mesentery (<1 mm and thick bone) or passing through bony protrusion, and type C indicates AEA having long mesentery (≥1 mm and thin mesentery).

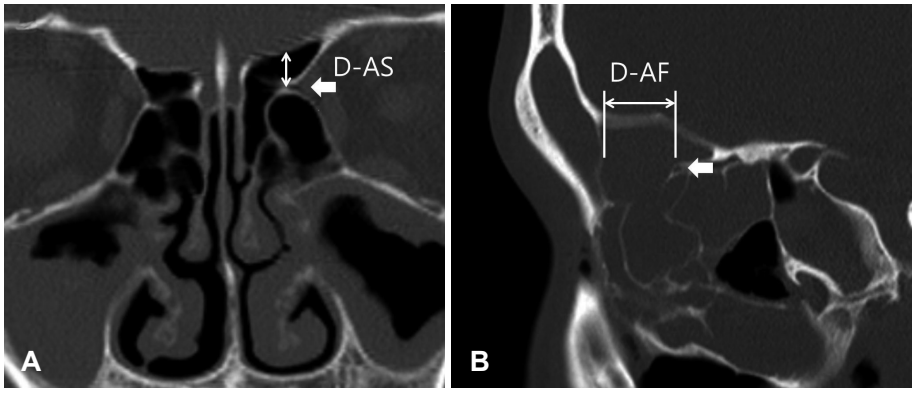

Fig. 2. Measurement of radiological parameter. The vertical distance between anterior skull base and AEA (D-AS) was measured at coronal section of computer tomography (A). The horizontal distance between AEA and posterior boundary of frontal sinus (D-AF) was measured at sagittal section image of computer tomography (B). White arrow indicates AEA. AEA: anterior ethmoid artery.

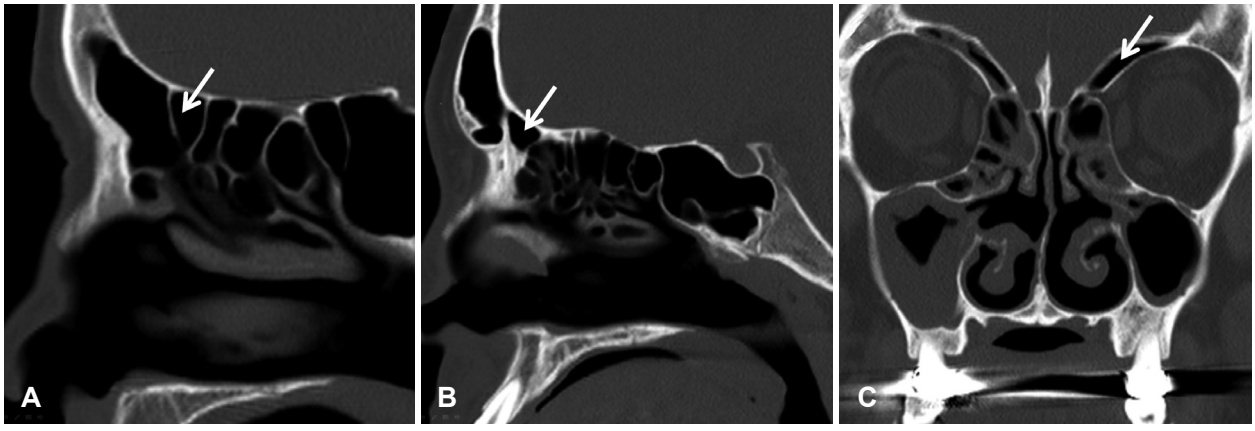

Fig. 3. Sagittal and coronal computed tomography scans showing ethmoidal cells around frontal recess. Suprabullar cell (white arrow)(A). Frontal bullar cell (white arrow)(B) and supraorbital cell (white arrow)(C).

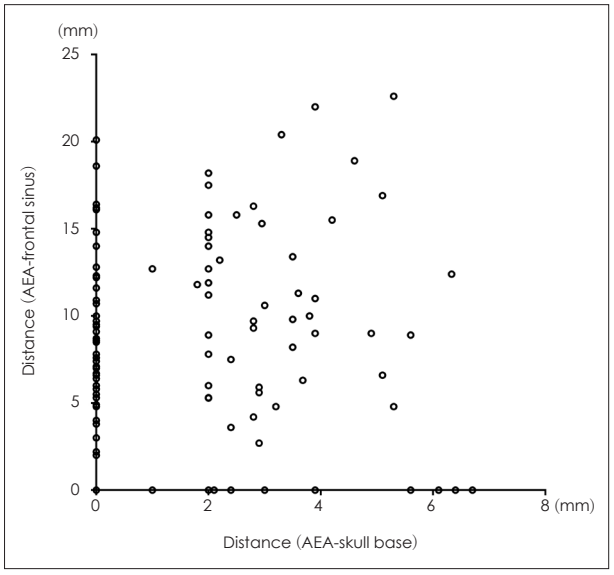

Fig. 4. The correlation between two distances (AEA to frontal sinus and AEA to anterior skull base). There was no statistically significant correlation (p=0.433). Pearson's correlation was used. AEA: anterior ethmoid artery.

lar cells according to their relationship with the frontal sinus, orbit, and anterior skull base. The definitions and descriptions of the cell types were adopted from a study by Lee, et al.,[17] the details of which are described in Fig. 3. With this definition, the number and subtype of each ethmoid air cells were counted and classified.

Data and statistical analysis

The association between the D-AS and D-AF was calculated with Pearson's correlation test. The analysis of variance test was employed to compare the number of intervening cells in three groups with different subtypes of AEA. A value of p <0.05 was considered statistically significant. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software (Version 12.0, SPSS Inc., Chicago, IL, USA).

Results

Characteristics of enrolled subjects

Among the 157 subjects, 70 subjects met the study criteria and their images were used for analysis. There were 49 male and 21 female subjects with a mean age of 56±9.26 years (range,

Table 1. Frequency of intervening ethmoid cells around frontal recess

	Supraorbital	Supra bullar	Frontal bullar	Total cell number
1 cell	14 (17.3%)	60 (74.1%)	7 (8.7%)	81 cells in 81 subjects
2 cells	3 (7.1%)	28 (66.7%)	11 (26.2%)	42 cells in 21 subjects

Table 2. Difference of intervening cell number in each anterior ethmoid artery (AEA) type

AEA type	Frequency	Cell number*
A	19 (16%)	1.11±0.66
B	40 (33.7%)	0.98±0.35
C	60 (50.5%)	0.89±0.58

*p=0.242, ANOVA was used

18−70 years). We carefully reviewed the reformed CT images of the 70 subjects (140 images, two nasal cavities for each patient) and in all 140 images the AEA were clearly identified on coronal images. However, on sagittal reconstruction images, the AEA was clearly demarcated on only 119 images and, thus, data from 119 nasal cavities were used for further analysis.

The anatomical relationship between the AEA and the frontal sinus

Among the 119 images, the AEA was located just behind the frontal recess in only 17 images (14%). In contrast, we were able to find one intervening ethmoid cell between the AEA and frontal recess on 81 images (68.1%). In 21 images (17.7%), there were two intervening ethmoid cells. The most frequent type of intervening cell was a supra bullar cell, followed by supraorbital and frontal bullar cells. We did not observe any images with three or more intervening cells. The frequency and type of the intervening cells between the AEA and frontal sinus are listed in Table 1.

The mean D-AF was 8.58±5.56 mm (0−22.6 mm) and the mean D-AS was 1.65±1.90 mm (0−6.7 mm). There was no statistically significant correlation between the D-AF and D-AS (p=0.433, Fig. 4). The AEA was classified according to the relationship with anterior skull base, and there were 19 images in group A (skull base type), 40 images in group B (short mesentery), and 60 images in group C (long mesentery). Differences in the number of cells for each AEA type are listed in Table 2. There were no statistically significant differences (p=0.242) in number of intervening cells between the three groups.

Discussion

There was an average distance of 8.58±5.56 mm between the posterior border of the frontal sinus and the AEA with a mean number of intervening cells of 1.2. The AEA was positioned directly behind the frontal sinus in only 14% of the nasal cavities. We assumed that the pneumatization around may affect D-AS and D-AF, and D-AS was employed as possible anatomical parameter for predicting the spatial relationship between AEA and frontal sinus in this study. However, the distance between the AEA and the anterior skull base did not predict the distance between the AEA and the frontal sinus. Our results suggest that in Asian patients there is no uniform anatomical relationship between the AEA and frontal sinus and the AEA might not be a good surgical landmark for finding the frontal sinus without a thorough review of thin section CT images.

There are several studies that have reported the relationship between the AEA and the frontal recess; however, there have been no anatomical studies in an Asian population. In 2006, Cho, et al.[16] reported that frontal recess pneumatization patterns differ in the Korean (Asian) and Caucasian adult populations. Specifically, supraorbital ethmoid cells were found to be more common in Caucasians while suprabullar cell and terminal recesses were more common in Koreans. Pneumatization patterns surrounding the frontal recess might have a significant effect on the relationship between the AEA and the frontal recess; therefore, we thought that the anatomical correlation between these two structures should be identified in Asian subjects. For this reason, our results are an important reference for performing endoscopic sinus surgery in Asian patients.

According to Simmen, et al.,[12] when ethmoid sinuses are more pneumatized and when there is a supraorbital cell, the AEA usually lies below the anterior skull base; therefore, they concluded that identifying the degree of pneumatization surrounding the frontal recess is important for identifying the course of the AEA. Additionally, in 2010, Lisbona, et al.[18] reported that ethmoid pneumatization and Keros grade may be predictive factors that are useful to determine the relationship between the AEA and anterior skull base. On the other hand, in the recent study by Eren, et al.[19] pnematization of the ethmoid cavity did not affect AEA localization in the term of lamellae. We did not observe any such relationship between AEA type and pneumatization patterns, which may be a difference attributable to racial differences or incidental errors. And

our study included 119 images and was relatively larger than previous studies. Given our results, it is difficult to determine that ethmoidal pneumatization surrounding the frontal recess is correlated with the anatomical location of AEA, especially in Asian patients.

The most frequent intervening cell type was the suprabullar cell, which was seen as one cell between the AEA and the frontal recess in 74.1% of cases and as two cells between these structures in 66.7% of cases. These results were not different than those of previous reports.[12] In addition, mesentery type (type C) AEA was the most prevalent type in our study, and this result is contrary to the result of previous study which reported that mesentery type was the least common type.[10,15] Considering the time gap and difference of enrolled subjects' age between two studies, there might be a trend of change in paranasal sinus anatomy.

Our study was conducted with only CT images, and there might be some discrepancy between CT images and actual operating fields. However, radio-anatomical studies have been previously conducted and high-resolution CT images were found to be sufficiently accurate to predict the location of the AEA.[3] Moreover, we employed sagittal reconstruction in all subjects to accurately identify the AEA, and cases with ambiguous AEA locations on CT images were excluded from our study.

In contrary to previous studies, we could not find any predictive anatomical and radiological factor for anticipating the relationship between the AEA and frontal sinus. Anatomical parameters such as the distance between the AEA and the anterior skull base and the attachment type of AEA to skull base were not a predictive factor to determine the relationship between the AEA and the frontal recess. Therefore thorough review of thin section CT scans is necessary before endoscopic sinus surgery.

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