THE STUDY OF VARIABILITY OF THE ANTERIOR ETHMOIDAL ARTERY IN HOSPITAL UNIVERSITI SAINS MALAYSIA

DR LIM ENG HAW

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF MEDICINE (OTORHINOLARYNGOLOGY-HEAD AND NECK SURGERY)

SCHOOL OF MEDICAL SCIENCES
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ABSTRAK (BAHASA MELAYU)

Objektif: Tujuan kajian in adalah untuk meneroka kebolehubahan arteri ethmoid anterior dalam kalangan populasi Malaysia dengan mengunakan skan tomografi berkomputer.

Kaedah: Ini merupakan satu kajian keratan rentas yang melibatkan analisasi 252 skan tomografi berkomputer sinus paranasal yang diperolehi di antara 1 Januari 2014 dan 31 Disember 2016. Imej multiplanar skan tomografi berkomputer dibina semula kepada gambaran aksial, koronal dan sagital dengan ketebalan potongan 1 mm. Hubungan di antara arteri ini dengan pangkalan tengkorak, kesan pneumatisasi sinus ethmoid ke atas hubungan ini dan jarak arteri ini dari titik rujukan penting yang bersebelahan juga dinilai.

Keputusan: Foramen ethmoid anterior telah dijumpai dalam 100%, tetapi kanal ethmoid anterior hanya dijumpai dalam 34.1%. 42.5% daripada arteri ethmoid anterior didapati berada di dalam pangkalan tengkorak, 20.2% berada di tahap pangkalan tengkorak dan 37.3% lagi melintasi secara bebas di bawah pangkalan tengkorak. Prevalens sel ethmoid supraorbital dan sel suprabullar masing-masing adalah 29.8% dan 48.0%. Terdapat hubungan statistik yang penting di antara kewujudan sel ethmoid supraorbital dengan kedudukan arteri ethmoid anterior di pangkalan tengkorak ($p < 0.001$). Purata ketinggian lamella lateral cribriform adalah 3.74 ± 1.01 mm. 42.1% daripada lamella lateral adalah di antara 1-3 mm dan 57.9% di antara 4-7 mm. Didapati bahawa dengan bertambahnya ketinggian lamella lateral, kemungkinan untuk arteri ethmoid anterior melintasi sinus ethmoid secara bebas bertambah ($p = 0.016$). Purata jarak arteri

ethmoid anterior dari pangkalan tengkorak adalah 1.93±2.03 mm, dari lantai orbit 21.91±2.47 mm dan 49.01±3.53 mm dari lantai hidung.

Kesimpulan: Kajian ini membekalkan pemahaman yang lebih terperinci tentang kebolehubahan arteri ethmoid anterior dan hubungannya dengan pangkalan tengkorak. Kami percaya bahawa maklumat-maklumat ini adalah amat penting untuk memastikan pembedahan endoskopik sinus yang selamat.

ABSTRACT (ENGLISH)

Objective: The aim of this study was to explore the variability of the anterior ethmoidal artery in Malaysian population by using computed tomography.

Methodology: This was a cross sectional study of 252 computed tomography of the paranasal sinuses acquired between 1st January 2014 and 31st December 2016. The multiplanar computed tomography images were reconstructed to axial, coronal and sagittal view at 1 mm slice thickness. The relationship of the artery with the skull base, the effect of the pneumatization of ethmoid sinus on this relationship and the distances of the artery from important adjacent reference points were assessed.

Results: The anterior ethmoidal foramen was seen in 100% of cases, whereas the anterior ethmoidal canal was only seen in 34.1%. 42.5 % of the anterior ethmoidal artery was found within the skull base, 20.2% at the skull base and the remaining 37.3% coursed freely below the skull base. The prevalence of the supraorbital ethmoid cell and the suprabullar cell were 29.8% and 48.0%, respectively. There was statistically significant association between the presence of the supraorbital ethmoid cell and the position of the anterior ethmoidal artery at the skull base ($p < 0.001$). The mean height of the lateral lamella of the cribriform plate was 3.74 ± 1.01 mm. The lateral lamella was 1-3 mm in 42.1% and 4-7 mm in 57.9%. With increase in the height of the lateral lamella, the probability for the anterior ethmoidal artery to course freely within the ethmoid sinus increases ($p = 0.016$). The mean distance of the anterior ethmoidal artery from the skull base was 1.93 ± 2.03 mm, from the orbital floor 21.91 ± 2.47 mm and 49.01 ± 3.53 mm from the nasal floor.

Conclusion: This study provides a better understanding of the variability of the anterior ethmoidal artery and its relationship with the skull base. We believe that these details are of paramount importance as a guide for surgeons to ensure a safe endoscopic sinus surgery.

Chapter 1
INTRODUCTION

1.1 INTRODUCTION

Endoscopic sinus surgery (ESS) has revolutionized the surgical management of sinonasal pathologies from the open surgery to the current day minimally invasive surgery.[1] The extent of ESS has dramatically increased over the past 2 decades and reaches from partial uncinectomy to extended surgery of the frontal, maxillary and sphenoid sinus.[2] While it is commonly undertaken, unfortunately ESS is not without complications. Complications related to ESS lie in its proximity to the orbit and anterior skull base and can be broadly divided into minor and major categories. Minor complications such as bleeding, infection, synechiae and recurrence are observed in 1.1-20.8% of cases, where major complications including cerebrospinal fluid (CSF) leak, orbital injury, intracranial injury and meningitis are seen in 0-1.5% of cases.[3]

Identifying the high risk areas where surgical complications are more likely to develop before ESS is essential. The thin lamina papyracea (LP), the cribriform plate (CP) and the lateral lamella of cribriform plate (LLCP) are amongst the most at risk areas in ESS.[4] Another vulnerable structure is the anterior ethmoidal artery (AEA) as it courses along the roof of ethmoid from the orbit to the anterior cranial fossa (ACF) from a posterolateral to anteromedial direction. Accidental injury to the AEA during surgery can result in significant bleeding and CSF leak. It is particularly troublesome if the lateral end of the artery is retracted into the orbit and causes a retrobulbar haematoma. Unless this is decompressed promptly, it can threaten the vision and lead to blindness. On the other hand, a medial injury where the artery enters the LLCP may result in CSF leak.[5]

It should be emphasized that routine identification of the AEA is usually unnecessary in ESS as this will increase the risk of damaging it.[6] Nonetheless, identification of the AEA has important significance in several occasions. The AEA serves as an important landmark for recognizing the frontal sinus and to define the superior limit of anterior skull base.[5,7] When approaching the frontal sinus, the artery that lies behind the posterior wall of the frontal recess can be used as landmark.[8] Considering the location of the AEA below the skull base, it can serve as a safety plane during surgery in this region. Any manipulation beyond this plane should be reminded of violating the skull base.[9] Infrequently, cauterization or ligation of AEA is necessary to control intractable posterior epistaxis. Some authors have recommended concurrent AEA ligation along with the ligation of the sphenopalatine artery (SPA) in cases of catastrophic epistaxis if the site of bleeding is not identified to reduce recurrences and therefore the need for repeated surgery. [10]

The position of the AEA in the ethmoid sinus has been reported to be very variable even in between the 2 sides of the same person. Ethnicity and gender have proven to cause these anatomical differences.[11] This variability inevitably places the artery at risk during ESS. In term of its distance from the anterior skull base, the artery may be closely opposed to the skull base, particularly when the roof of ethmoid is low, or courses freely below the skull base within a bony canal and being connected to skull base by a thin bony mesentery.[5,12,13] This relationship of the AEA with the skull base is important because the chance of injuring the artery during surgery is higher if it lies below the skull base.

It is of utmost important to master the relevant anatomy and its possible variations before one embarks upon ESS. Several cadaveric and radiographic studies have contributed to the current understanding of the surgical anatomy of the AEA. However, most of the previous studies have focused on Caucasian population and there have been very limited information on our population. Therefore, this study was conducted to explore the variability of the AEA in our local population by using computed tomography (CT) scan because CT technique is superior in depicting bony structures which are used for indirect identification of the AEA. The relationship of the AEA with the skull base, the effect of the pneumatization of ethmoid sinus on this relationship and the distance of the AEA from important adjacent reference points were also assessed. We believe that these details are of paramount importance to ensure a safe ESS.

Chapter 2
OBJECTIVES

2.1 GENERAL OBJECTIVE

To study variability of the anterior ethmoidal artery in patients attending Hospital Universiti Sains Malaysia

2.2 SPECIFIC OBJECTIVES

1. To study the prevalence of supraorbital ethmoid cell
2. To study the prevalence of suprabullar cell
3. To determine the association between supraorbital ethmoid cell with the position of anterior ethomidal artery at the skull base
4. To measure the distance of anterior ethmoidal artery from skull base, orbital floor and nasal floor
5. To determine the association between the Keros and Yenigun classification with the position of anterior ethmoid artery at the skull base

Chapter 3
MANUSCRIPT

3.1 TITLE PAGE

ANATOMICAL VARIATIONS OF ANTERIOR ETHMOIDAL ARTERY IN MALAYSIAN PATIENTS: A RADIOLOGICAL STUDY

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3.2 ABSTRACT

Objective: The aim of this study was to explore the variability of the anterior ethmoidal artery in Malaysian population by using computed tomography.

Design: This was a cross sectional study of computed tomography of the paranasal sinuses.

Setting: Tertiary academic medical center.

Participants: Subjects who underwent computed tomography of paranasal sinuses in Hospital Universiti Sains Malaysia between 1st January 2014 and 31st December 2016. A total of 252 computed tomography scans were analyzed.

Main outcomes measures: The multiplanar computed tomography images were reconstructed to axial, coronal and sagittal view at 1 mm slice thickness. The relationship of the artery with the skull base, the effect of the pneumatization of ethmoid sinus on this relationship and the distances of the artery from important adjacent reference points were assessed.

Results: The anterior ethmoidal foramen was seen in 100% of cases, whereas the anterior ethmoidal canal was only seen in 34.1%. 42.5 % of the anterior ethmoidal artery was found within the skull base, 20.2% at the skull base and the remaining 37.3% coursed freely below the skull base. The prevalence of the supraorbital ethmoid cell and the suprabullar cell were 29.8% and 48.0%, respectively. There was statistically significant association between the presence of the supraorbital ethmoid cell and the position of the anterior ethmoidal artery at the skull base ($p < 0.001$). The mean height of the lateral lamella of the cribriform plate was 3.74 ± 1.01 mm. The height of the lateral lamella was 1-3 mm in 42.1% and 4-7 mm in 57.9%. With increase in the height of the lateral lamella, the probability for the anterior ethmoidal artery to course freely within the ethmoid sinus increases ($p = 0.016$). The mean distance of the anterior ethmoidal artery from the skull base was 1.93 ± 2.03 mm, from the orbital floor 21.91 ± 2.47 mm and 49.01 ± 3.53 mm from the nasal floor.

Conclusion: This study provides a better understanding of the variability of the anterior ethmoidal artery and its relationship with the skull base. We believe that these details are of paramount importance as a guide for surgeons to avoid potential complication and to ensure a safe endoscopic sinus surgery.

Keywords: Anterior ethmoidal artery; cribriform plate; supraorbital cell; skull base

3.3 INTRODUCTION

The anterior ethmoidal artery (AEA) is a structure of great interest to surgeon in endoscopic sinus surgery (ESS) and is regarded as an important landmark to locate the frontal sinus and anterior skull base.[1,2,3] The AEA exhibits considerable variability as it crosses the ethmoid sinus from the orbit in an anteromedial direction to reach the lateral lamella of the cribriform plate (LLCP).[4] Poor recognition of this variability place the artery at risk during endoscopic sinus surgery. Iatrogenic injury to the AEA can result in major complications such as disastrous bleeding and cerebrospinal fluid leak. Therefore, detail knowledge of the relevant anatomy of the AEA and its possible variation is essential to avoid potential complication during endoscopic sinus surgery. A preoperative computed tomography (CT) is undoubtedly useful in evaluating the complex anatomy of the AEA.[5]

Several cadaveric and radiographic studies have contributed to the current understanding of the surgical anatomy of the AEA. However, most of the previous studies have focused on Caucasian population and there have been very limited information on Asian population. This study was conducted to determine the variability of the AEA in Malaysian population by using CT scan because CT technique is superior in depicting bony structures which are used for indirect identification of the AEA. The relationship of the AEA with the skull base, the effect of the pneumatization of ethmoid sinus on this relationship and the distances of the AEA from important adjacent reference points were also assessed.

3.4 METHODOLOGY

This was a cross sectional study of the CT scan done at the Department of Radiology, Hospital Universiti Sains Malaysia, Kelantan. An analysis of 252 CT of the paranasal sinuses (CT PNS) acquired between 1st January 2014 and 31st December 2016 was conducted over a duration of 1 year.

Subjects age 18 years and above who underwent CT PNS in Hospital Universiti Sains Malaysia were included in this study. The following exclusion criteria were adopted: subjects with craniofacial anomaly, sinonasal tumour, nasal polyposis, skull base or facial trauma, or previous surgery to the PNS and skull base. The sample size was calculated using Power and Sample Size Calculations program version 3.1.2. The sampling method was simple random sampling using computer software www.randomizer.org. The study protocol was reviewed and approved by Research Ethics committee (Ethical Approval No. USM/JEPeM/16070232) and was performed in adherence with the Declaration of Helsinki. All data were anonymous and only accessible to the research team members. Data were presented as grouped data and the responders were not identified individually.

The CT PNS were retrieved from radiology information system (RIS) and picture archive communication system (PACS). These CT PNS images were acquired from SOMATOM ® Definition AS+ (Siemens Healthcare GmbH, Germany) which is capable of producing 128 slices of images per rotation. The multiplanar CT images were reconstructed to axial, coronal and sagittal view at 1 mm slice thickness. The CT images were interpreted by 1 radiologist, 1 otorhinolaryngologist and the investigator. All measurements were taken 3 times and the average was used in data analysis. When there was discordant opinion, further evaluation of the particular image was done by the specialists to obtain a mutual consensus. All data obtained were entered in the study proforma.

The CT image was evaluated on coronal and axial views to look for the supraorbital ethmoid cell (SOEC) (Figure 1) and then on sagittal view for the presence of suprabullar cell (SBC) (Figure 2). The AEA was identified on the coronal view using the adjacent bony landmarks namely the anterior ethmoidal foramen (AEF) (Figure 3) and the anterior ethmoidal canal (AEC) (Figure 4) if present. Following the identification of the AEA, the distances between the artery and the skull base (Figure 5), orbital floor (Figure 6) and nasal floor (Figure 7) were measured. The height of the lateral lamella of the cribriform plate (LLCP) was measured on the coronal view that showed the lowest cribriform plate (Figure 8). The anteroposterior dimension of the LLCP was measured by tracing it on the axial view with the endpoint of crista galli as the posterior boundary (Figure 9).

All data obtained were transferred into the Statistical Package for Social Sciences (SPSS) software version 22.0. Descriptive analysis was used to calculate the prevalence of the SOEC and the SBC. Descriptive analysis was also used to analyze the distance of the AEA from various anatomical reference points. Pearson's Chi-squared test was used to determine the association between the presence of the SOEC and SBC with the position of the AEA as well as the association between the height and the anteroposterior dimension of the LLCP with the position of the AEA. $p < 0.05$ was considered statistically significant.

3.5 RESULTS

This study involved 126 subjects consisting of 72 males and 54 females. The age ranged from 18 to 86 years with mean age of 52.09 ± 18.48. In term of the race, there were 106 Malays (84.1%), 15 Chinese (11.9%), 1 Indian (0.8%) and 4 (3.2%) others, representing local ethnic ratio (Table 1).

A total of 252 AEA were analyzed. The AEF which was identified as the notch on the medial wall of the orbit was seen in 100% of cases, whereas the AEC was only seen in 34.1%. The SOEC and the SBC were present in 29.8% and 48% of cases, respectively (Table 2). 42.5 % of the AEA was found within the skull base (Figure 10), 20.2% at the skull base (Figure 11) and the remaining 37.3% coursed freely below the skull base (Figure 12). In the presence of SOEC, the AEA coursed freely in the ethmoid sinus in 81.3%, whereas this only occurred in 18.6% of AEA when the SOEC was absent ($p < 0.001$) (Table 3).

The mean height of the LLCP was 3.74 ± 1.01 mm (1.00-7.00 mm). The LLCP was 1-3 mm (Type I Keros) in 106 sides and 4-7 mm (Type II Keros) in 146 sides. There was no Type III Keros (LLCP of 8-16 mm) seen in our study. It was found that with the increase in height of the LLCP, the probability for the AEA to course freely within the ethmoid sinus increases. This association between the height of the LLCP and the position of the AEA was statistically significant ($p = 0.016$) (Table 4).

When comparing the height of both LLCP in the same person, asymmetry (≥ 1 mm) was found in 51 subjects (Figure 13). The LLCP was higher on the right side in 25 subjects and on the left side in 26 subjects, which was almost equal. The mean anteroposterior length of the LLCP was 7.44 ± 1.32 mm (4.00-12.00 mm). The anteroposterior length of the LLCP was 6-10 mm (Type I Yenigun) in 246 sides and 11-15 mm (Type II Yenigun) in the remaining 6 sides. Our study did not show any statistically significant association between the anteroposterior length of the LLCP and the position of the AEA.

The mean distance of the AEA from the skull base was 1.93 ± 2.03 mm (0-7.50 mm), from the orbital floor 21.91 ± 2.47 mm (17.05-30.35 mm) and 49.01 ± 3.53 mm (40.90-57.90 mm) from the nasal floor (Table 5).

3.6 DISCUSSION

Landmarks for identification of the AEA

Many studies have provided some guidelines to improve the identification and localization of the artery during ESS.[6,7,8,9] Indirect identification of the AEA through the adjacent bony landmarks has been widely applied. To this point, the CT technique is superior as it depicts bony structures better compared to other imaging modalities. We found that the AEF on the medial wall of the orbit was a reliable reference to locate the AEA since it was seen in 100% of cases in our study. Souza et al. [2] and Gotwald et al. [7] showed that the AEF was found in 100% and 95% of cases, respectively. These findings were similar to our study.

The AEA and the skull base

In the ethmoid sinus, the course of the AEA varies depending on its relation to the skull base. In our study, we found that the artery was closely appose to the skull base in 62.7% of cases and coursed freely in the ethmoid sinus below the skull base in the remaining 37.3%. In the former group, 42.5% of the artery was completely embedded within the skull base and 20.2% coursed at the level of skull base producing some degree of bony protrusion (Fig. 11). These findings correspond to studies done by Moon et al. [1], Simmen et al. [5], Basak et al. [6], Araujo et al. [10], Lannoy et al. [11] and McDonald and Robinson. [12], in which majority of the artery was found at the level of the skull base. On the contrary, Cankal et al. [8], Kainz and Stammberger [13], Yang et al. [14] and Joshi et al. [15] reported that greater number of AEA was located below the skull base with a mesentery connecting it to the skull base. These discrepancies demonstrate the wide variations in the position of the artery even among the same ethnicity. Recognition of these variations prior to surgery aids to minimize the risk of injuring the artery, especially when the artery is low lying below the skull base. If the AEA is not recognized as a mesentery, the artery might be accidentally injured while clearing septations on the skull base.[16]

The AEA and the pneumatization of the ethmoid sinus

The prevalence of SOEC in our study was 29.8%. This is in agreement with all previous studies done, which showed prevalence between 15.0-55.8 %. [2,5,9,15,17,18,19] The wide range of prevalence is probably attributable to the difference in the sample size, methodology or ethnicity. SOEC refers to the anterior ethmoid cell that arises from pneumatization of the orbital plate of the frontal bone. It extends superolaterally over the orbit from the frontal recess. There is a statistically significant association between the presence of SOEC and the distance of the AEA from the skull base. In the presence of a SOEC, 81.3% of the AEA was located at a farther distance below the skull base, whereas this was only seen in 18.6% when the SOEC was absent ($p < 0.001$). Therefore, the presence of SOEC serves as a guide that the AEA is far below the skull base and at risk of injury during an ESS.[5,15]

The anterior ethmoidal artery and the LLCP

The LLCP is part of ethmoid bone that constitutes the lateral border of the olfactory fossa. Keros classification was used to classify the height of the LLCP. In Keros type I, the height of the LLCP is 1-3 mm, 4-7 mm in Keros type II and 8-16 mm in Keros type III (Figure 5). In the first study by Keros [20], type I was found in 12% of cases, type II 70% and type III 8%. Our study also found that type II Keros was the most common, seen in 57.9%, whereas type I was found in 42.1%. When comparing the height of LLCP between both sides in the same subjects, our study showed that 40.5% of subjects had asymmetry LLCP (≥ 1 mm). Some authors observed that the right LLCP was lower. [21] In our study, we found the left LLCP was lower in 51% of cases. No type III Keros has been found in our study. This finding was consistent with a study done by Alazzawi et al. [22] in Malaysia, that reported no type III Keros.

The height of the LLCP was found to be a reliable predictor of the position of the AEA at the skull base. [2,23,24] The AEA travels freely in the ethmoid sinus below the skull base in greater frequency if the LLCP is taller and the olfactory fossa is lower.[25] This association between the height of the LLCP and the position of the AEA was found to be statistically significant in our study (p = 0.016). Modification of Keros classification by Yenigun et al. [19] that includes the measurement of the anteroposterior length of the LLCP had discovered that the AEA is also more likely to run freely below the skull base with the increase of the length of the LLCP. However, we did not find similar findings in our study. We attribute this difference to incidental error or methodological difference. In our study, the length of the LLCP is measured at the oculomeatal plane and this was not specified by Yehigun et al.

Measurements

In our study, the distances between the AEA and the nasal floor, orbital floor were measured. The mean distance between the AEA and the nasal floor was 49.01 ± 3.53 mm. The mean distance was similar to the study done in the Korean population by Moon et al. [1], in which this distance was 49.0 ± 4.9 mm, while studies Caucasian population by Araujo et la. [10] and Monjas-Cánovas et al. [17] found a slightly longer distance of 61.72 ± 4.18 mm and 55.51 ± 5.52 mm. The mean distance between the AEA and the orbital floor was 21.91 ± 2.47 mm. Given the fact that orbital floor is a fixed anatomical landmark that is rarely distorted by pathology or surgery, this distance can provide the surgeon useful information to locate the AEA during ESS.[26] However, this distance was not mentioned in any of the previous study, hence it was difficult to draw comparison. These measurements could be useful references for surgeon in estimating the extent of space for manipulation of instruments during ESS.

3.7 CONCLUSION

There are wide variations of the AEA position and it is importance to identify them in a specific population because ethnicity had been proven to cause these differences. This study provides surgeons with better understanding of the variable positions of the AEA in Malaysian population which is of paramount importance to ensure a safe endoscopic sinus surgery.

3.8 REFERENCES

1. Moon HJ, Kim HU, Lee JG, et al. Surgical anatomy of the anterior ethmoidal canal in ethmoid roof. Laryngoscope 2001; 111:900–904
2. Souza SA, Souza MM, Gregório LC, et al. Anterior ethmoidal artery evaluation on coronal CT scans. Braz J Otorhinolaryngol 2009; 75:101-106
3. Stammberger H, Posawetz W. Functional endoscopic sinus surgery. Concept, indications and results of the Messerklinger technique. Eur Arch Otorhinolaryngol 1990; 247:63-76
4. Lee WC, Ku PKM, Hasselt CA. New guidelines for endoscopic localization of the anterior ethmoidal artery: a cadaveric study. Laryngoscope 2000; 110:1173-1178
5. Simmen D, Raghavan U, Briner HR, et al. The surgeon's view of the anterior ethmoidal artery. Clin Otolaryngol 2006; 31:187-191
6. Basak S, Karamam CZ, Mutlu C, et al. Evaluation of some important anatomical variations and dangerous areas of the paranasal sinuses by CT for safer endonasal surgery. Rhinology 1998; 36:162-167
7. Gotwald TF, Menzler A, Beauchamp NJ, et al. Paranasal and orbital anatomy revisited: identification of the ethmoid arteries on coronal CT scans. Crit Rev Comput Tomogr 2003; 44:263-278
8. Cankal F, Apaydin N, Acar HI, et al. Evaluation of the anterior and posterior ethmoidal canal by computed tomography. Clin Radiol 2004; 59:1034–1040
9. Noori FM, Ali MA, Karim R, et al. Observation of anterior ethmoidal artery in Coronal CT scans of paranasal sinuses in patients attending Katihar Medical College, Katihar. Ann. Int. Med. Den. Res 2017; 3(2):EN04-EN06

10. Araujo FBC, Weber R, Pinheiro NCD, et al. Endoscopic anatomy of the anterior ethmoidal artery: a cadaveric dissection study. Rev Bras Otorrinolaringol (Engl Ed) 2006; 72:303-308
11. Lannoy-Penisson L, Schultz P. The anterior ethmoidal artery: radio-anatomical comparison and its application in endonasal surgery. Acta Otolaryngol 2007; 127:618-622
12. McDonald SE, Robinson PJ. Radiological anatomy of the anterior ethmoidal artery for functional endoscopic sinus surgery. J Laryngol Otol 2008; 122:264-267
13. Kainz J, Stammberger H. The roof of the anterior ethmoid: a locus minoris resistentiae in the skull base. Laryngol Rhinol Otol 1988; 67:142-149
14. Yang YX, Lu QK, Liao JC, et al. Morphological characteristics of the anterior ethmoidal artery in ethmoid roof and endoscopic localization. Skull Base 2009; 19:311–317
15. Joshi AA, Shah KD, Bradoo RA. Radiological correlation between the anterior ethmoidal artery and the supraorbital ethmoid cell. Indian J Otolaryngol Head Neck Surg 2010; 62:299-303
16. Siow JK. The "Mesentery" of the anterior ethmoid artery. Ann Otolaryngol Rhinol 2016; 3:1084
17. Monjas-Cánovas I, García-Garrigós E, Arenas-Jiménez JJ, et al. Radiological anatomy of the ethmoidal arteries: CT cadaver study. Acta Otorrinolaringol Esp 2011; 62:367-374
18. Jang DW, Lachanas VA, White LC, et al. Supraorbital ethmoid cell: a consistent landmark for endoscopic identification of the anterior ethmoidal artery. Otolaryngol Head Neck Surg 2014; 15:1073–1077
19. Yenigun A, Goktas SS, Dogan R, et al. A study of the anterior ethmoidal artery and a new classification of the ethmoid roof (Yenigun classification). Eur Arch Otorhinolaryngol. 2016; 273:3759-3764

20. Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. Z Laryngol Rhinol Otol Ihre Grenzgeb 1962; 41:808-813

21. Souza SA, Souza MMA, Idagawa M, et al. Computed tomography assessment of the ethmoid roof: a relevant region at risk in endoscopic sinus surgery. Radiol Bras 2008; 4:143–147

22. Alazzawi S, Omar R, Rahmat K, et al. Radiological analysis of the ethmoid roof in the Malaysian population. Auris Nasus Larynx 2012; 39:393–396

23. Floreani SR, Nair SB, Switajewski MC, et al. Endoscopic anterior ethmoidal artery ligation: a cadaver study. Laryngoscope 2006; 116:1263-1267

24. Poteet PS, Cox MD, Wang RA, et al. Analysis of the relationship between the location of the anterior ethmoid artery and Keros classification. Otolaryngol Head Neck Surg. 2017; 157(2):320-324

25. Stammberger H, Lund VJ. Anatomy of the nose and paranasal sinuses. In: Gleeson M, Browning GG, Burton MJ, et al, eds. Scott-Brown’s Otorhinolaryngology: Head and Neck Surgery 7 Ed. Vol2. CRC Press; 2008;1335

26. Wuttiwongsanon C, Chaowanapanja P, Harvey RJ, et al. The orbital floor is a surgical landmark for the Asian anterior skull base. Am J Rhinol Allergy 2015; 29:216-219

3.9 TABLES AND FIGURES

Table 1: Dermographic data of study subjects.

Dermographic characteristics	Minimum	Maximum	Mean	SD*
Age	18	86	52.1	18.48
	Case		%	
Gender				
Male	72		57.14	
Female	54		42.86	
	126		100	
Race				
Malay	106		84.13	
Chinese	15		11.90	
Indian	1		0.79	
Others	4		3.18	
	126		100	

Table 2: The prevalence of suprabullar cell and supraorbital ethmoid cell.

Prevalence	Suprabullar cell		Supraorbital ethmoid cell	
	Side	%	Side	%
Present			75	29.8
Absent			177	70.2
Total	252	100	252	100

Table 3: Association between supraorbital cell and position of anterior ethmoidal artery. Pearson's chi-squared test applied shows that there is a significant association between supraorbital cell and anterior ethmoidal artery position (χ^2 (2) = 96.27, *p*-value < 0.001).

Supraorbital cell	**AEA position**						***p*-value**[a]
	Within skull base		At skull base		On mesentery		
	Side	%	Side	%	Side	%	
Absent	105	59.3	39	22.0	33	18.6	< 0.001
Present	2	2.7	12	16.0	61	81.3	

[a] Zero cells (0.0%) have expected count less than 5; Pearson's Chi-squared test was applied, χ^2(2) = 96.27

Table 4: Association between Kenos classification and the position of anterior ethmoidal artery. Pearson's chi-squared test applied shows that there is a significant association between Kenos classification and anterior ethmoidal artery position (χ^2(2) = 8.30, *p*-value = 0.016).

Keros classification	**AEA position**						***p*-value**[a]
	Within skull base		At skull base		On mesentery		
	Side	%	Side	%	Side	%	
Type I	56	52.8	19	17.9	31	29.2	0.016
Type II	51	39.4	32	21.9	63	43.2	
Type III	0	0.0	0	0.0	0	0.0	

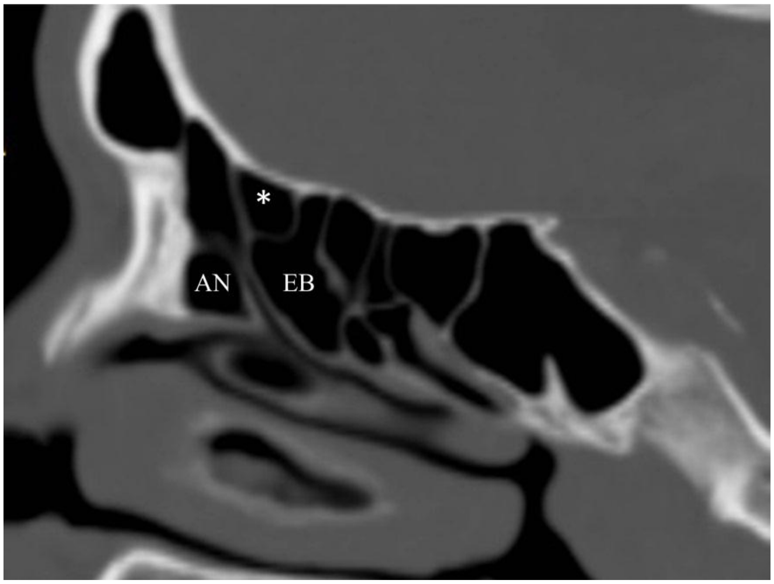
[a] Zero cells (0.0%) have expected count less than 5; Pearson's Chi-squared test was applied, χ^2(2) = 8.30

Table 5: The distances of the AEA from the skull base, orbital floor and nasal floor.

Distance (mm)	Minimum	Maximum	Mean	SD*
AEA-Skull base	0	7.50	1.93	2.03
AEA-Orbital floor	17.05	30.35	21.91	2.47
AEA-Nasal Floor	40.90	57.90	49.01	3.53

*SD = Standard deviation

Figure 1: Coronal CT showed supraorbital ethmoid cell (asterisk) extending over the orbit.



AN, agger nasi cell; EB, ethmoid bulla.

Figure 2: Sagittal CT showed suprabullar cell (asterisk) above the ethmoid bulla.