Vertical Basal Lamella of Middle Turbinate and Bulla Lamella: Important Landmarks for Endoscopic Localization of Anterior Ethmoidal Artery

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Objective: *To examine the prevalence of an anterior ethmoidal artery (AEA) that located below the skull base and the locations in relation to fixed anatomical structures.*
Material and Method: *Computed tomography (CT) data relating to paranasal sinuses of 100 consecutive patients were obtained using a 128 multidetector high-resolution CT scanner (Phillips®). Thin slice axial CT was performed and images in coronal and sagittal planes were reconstructed. Entrance and exit points of the AEA were determined. Locations of AEAs in relation to the skull base were assessed independently by two assessors. The distance between the AEA and the skull base, the bulla lamella/the anterior wall of ethmoidal bulla (BL/AWEB) and the vertical basal lamella of the middle turbinate (BLMT) were measured.*
Results: *The AEA was found to locate below the skull base in 72.5%. The mean distance between the AEA and the skull base was 3.2 mm. Nearly 95% of the AEAs were located between the BL/AWEB and the BLMT, and only 5% was at or behind the BLMT. 71.0% of the AEAs located posteriorly to the midpoint of the distance between the BL/AWEB and the BLMT. The mean distance from the BL/AWEB was 7.3 mm.*
Conclusion: *Most of the AEAs located below the skull bases in Thais and being posteriorly to the midpoint of the distance between the BL/AWEB and the BLMT. The BLMT and the BL/AWEB were two fixed constant anatomical features that may be used as optional landmarks for endoscopic localization of the AEAs.*

Keywords: *Anterior ethmoidal artery, skull base, bulla lamella, middle turbinate*

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Anterior ethmoidal artery (AEA) is a branch of the ophthalmic artery that enters the anterior ethmoid sinus through the anterior ethmoidal foramen and exits through the lateral lamella of the cribriform plate. It is one of the major arteries supplying the ethmoid sinus and nasal mucosa. Injury to this artery during sinus surgery will expose the patient to the risk of orbital hematoma and blindness[1].

The course of this artery within the anterior ethmoid sinus relates to the fovea ethmoidalis or skull base. Its location is either below the skull base i.e. 'hanging'[2-5], or at the skull base within bony canal/ dehiscent canal i.e. 'non-hanging'[5]. Locations of AEAs are of great importance to surgeons because either 'hanging' AEAs or even 'non-hanging' AEAs within dehiscent canals may possess a greater risk of injury during surgical procedures. Thus, investigations and determinations of the locations of AEAs using computed tomography (CT) of paranasal sinuses (PNSs) before sinus surgery is a pre-requisite to reduce risk and avoid surgical injury i.e. iatrogenic complication.

In spite of numerous studies on locations of AEA either by CT of PNSs or by cadaveric dissection[4-11], such studies from western countries demonstrated consistent results that 57.1-84.0% of the AEAs were mostly located at the skull base[2-9].

However, some different findings were reported by studies from Asian cadavers by Yang et al[10] from China and Moon et al[11] from Korea. These previous studies demonstrated a higher percentage of 83.3% (95% CI 66.4 to 92.7) in 15 cadavers where AEAs ran freely in ethmoid sinuses[10]; whilst, a much lower

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percentage of 14.3% (95% CI 8 to 24.3) was reported by the latter in 30 cadavers[11]. The wide range of 95% CI on prevalence of hanging AEAs provided sufficient indication for research on the locations of AEA by using multiplanar multislice CT with axial, coronal and sagittal views among Thai patients.

The aims of this study were to examine: (i) the prevalence of hanging/below the skull base AEA in the ethmoid sinus, and (ii) the relationship of the AEAs to fixed anatomical landmarks e.g., the bulla lamella/ anterior wall of the ethmoid bulla (BL/AWEB i.e. 2nd ethmoturbinal) and the vertical basal lamella of the middle turbinate (BLMT i.e. 3rd ethmoturbinal) which might be useful for localization of AEA during endoscopic sinus surgery.

Material and Method

This was a retrospective descriptive study, conducting at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Thailand. Consecutive CTs of paranasal sinuses of patients performed since November 2012 were retrieved. Starting with the most recent, we worked backwards till we reached 100 cases (200 sides). Inclusion criteria were CT images of Thai patients, aged at least 18 years. Excluded CTs were those presenting with any history of injury or operation of intranasal structure, paranasal sinus and base of skull, congenital craniofacial deformity, nasal/paranasal sinus tumor obscuring the interpretation of the AEA anatomy, asymmetrical nasal cavities/paranasal sinus and any case in which the AEA was not visualized. CT PNS were performed using a multiplanar multislice CT scanner (Philips®), brilliance ICT 128 slices with a collimator of 0.75 mm, 120 kV, and 100 mAs by displaying coronal, axial and sagittal views. Axial CT included hard palate inferiorly and frontal sinus superiorly, and coronal CT included anterior wall of frontal sinus anteriorly and sphenoid sinus posteriorly. The planes of axial and coronal cuts were parallel and perpendicular to the hard palate, respectively, while the plane of sagittal cut was also perpendicular to the hard palate. The slice thickness of 1 mm and the interval of 0.5 mm with a bone window technique was used. One rhinologist (ST) and one experienced head and neck radiologist (WP) reached consensus on the identification of the entrance and exit of the AEA from the axial view and confirmed this with the coronal view.

The sites of entrance and exit of the AEA could be demonstrated simultaneously in axial, coronal and sagittal views by using the 'Intellilink' icon in the Synapse system. The locations of the AEAs in relation to the skull base were assessed independently by the rhinologist and the head & neck radiologist and consensus was reached if there was disagreement. Using a ruler icon in the Synapse system and the sagittal view, the distances between the AEA and the skull base (measured vertically to the hard palate), BL/AWEB (measured in parallel with the hard palate) and BLMT (measured in parallel with the hard palate) were measured by a rhinologist. Direction of the AEA from entrance to exit and the site of exit were decided by the consensus of the rhinologist and the radiologist.

A requirement for a sample size of 100 CTs was estimated from a pilot study of 30 scans of 54% hanging AEAs, with alpha error of 0.05 and precision of 10%. Descriptive statistics were used. Nominal data were presented as percentage and 95% CI, whereas continuous data were presented as mean, range and 95% CI. This study was approved by the Khon Kaen University Ethics Committee in Human Research (HE551395).

Results

To obtain 100 eligible scans, 256 CT scans were retrieved. Out of these, 17 scans were excluded because of age (the subjects aged less than 18 years) and 139 scans were excluded because of previous nasal/ sinus surgery and the nasal/paranasal sinus tumor obscured the AEA. The scans were from 43 males and 57 females, with the ages from 18 to 88 years. During assessments, BLMT were unable to be identified clearly at the entrances in 14 cases and at exits in 23 sites. The relationships of the AEA and skull base are shown in Table 1, and Fig. 1 and 2. The AEA located below the skull base in 72.5% (95% CI 65.8 to 79.0) of the subjects. The mean distance between the AEAs and the skull bases at the entrance was 3.4 mm (95% CI 3.2 to 3.6, range 0.7 to 8.6) and at the exit was 2.8 mm (95% CI 2.5 to 3, range 0.7 to 11.9). The direction of the AEA from entrance to exit was anteromedial in 94.5% (95% CI 90. to 97.2), while 5.5 % (95% CI 2.8 to 9.6) ran horizontally (Fig. 2).

The relationships of the AEA to the BL/AWEB and the BLMT are shown in Table 2 and 3. The AEAs

Table 1. Locations of AEA in relation with base of skull (Total n = 200)

	n	%	95% CI
At base of skull	55	27.5	21.4-34.2
Below base of skull	145	72.5	65.8-79.0

were found in between the BL/AWEB and the BLMT in 95.0% (95% CI 91.5 to 98.1); at the entrances were 95.7% (95% CI 91.7 to 98.1), whereas 94.4% (95% CI 89.9 to 97.3) were at the exits. Only 5% (95% CI 3.2 to 7.7) was found at or behind the BLMT.

In regard to the locations between the BL/AWEB and the BLMT, 71.0% (95% CI 65.9 to 75.8) were in the posterior half. The mean distance of AEA from the BL/AWEB was 7.3 mm (95% CI 7 to 7.6, range 1 to 16): 7.3 mm (95% CI 6.8 to 7.8, range 1 to 16.0) at the entrances, and 7.2 mm (95% CI 6.7-7.7, range 1-15) at the exits.

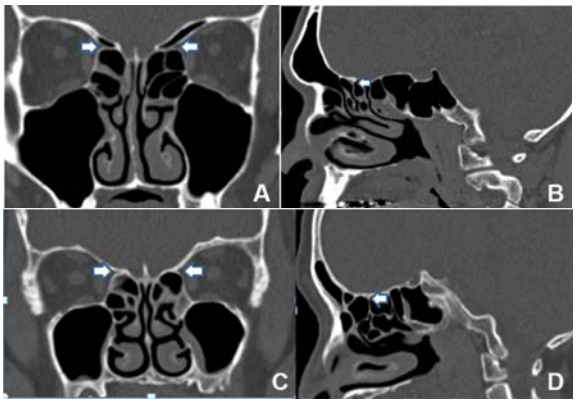

Fig. 1 Relationships of AEA (arrow) and skull base: AEA below skull base: coronal view (A), sagittal view (B). AEA at skull base: coronal view (C), sagittal view (D).

Discussion

This CT study demonstrated that most (72.5%) of the AEAs in Thais ran freely in ethmoid sinus. This high prevalence was in contrast to 14.3% from the CT and cadaveric study in Korea by Moon et al[11]. This difference may be explained by the differences in the efficacy of CT scanner in 2001 compared with ours in 2012 and the plane that was used by Moon et al was only a sagittal view. However, the prevalence in this present study was similar to the 83.3% in a cadaveric Chinese study by Yang et al from China[9]. Such high prevalence of 'below the skull' provided contrast to reports from western countries which showed that most AEAs located at the skull base and ranged from 57.1 to 73.7% (Table 4)[2-7,9]. Possible explanations

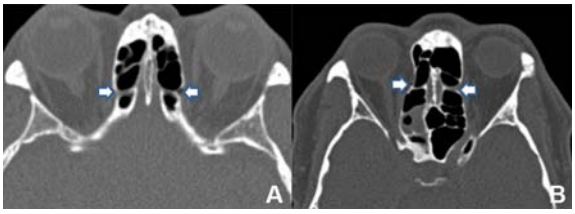

Fig. 2 Direction of AEA: A) Anteromedial direction, B) Horizontal direction.

Table 2. Relationships between AEA & bulla lamella/anterior wall of ethmoid bulla (BL/AWEB) and vertical basal lamella of middle turbinate (BLMT)

	Entrance Site			Exit Site			Total		
	n	%	95% CI	n	%	95% CI	n	%	95% CI
Between BL/AWEB & BLMT	178	95.7	91.7-98.1	167	94.4	89.9-97.3	345	95.0	91.5-98.1
At or posterior to BLMT	8	4.3	1.9-8.3	10	5.7	2.7-10.1	18	5.0	3.2-7.7
TOTAL	186			177			363		

Table 3. Relationship of the AEA to the midpoint of the distance between the bulla lamella/ethmoid bulla and the vertical basal lamella of middle turbinate

	Entrance Site			Exit Site			Total		
	n	%	95% CI	n	%	95% CI	n	%	95% CI
Anterior	55	30.9	24.6-38.0	45	26.9	20.8-34.1	100	29.0	24.5-34.0
Posterior	123	69.1	61.8-75.8	122	73.1	65.7-79.6	245	71.0	65.9-75.8
TOTAL	178			167			345		

Table 4. CT studies of AEA from various studies

Authors/years	Country	CT view	Total N	At skull base		Below skull base	
				n	% (95% CI)	n	% (95% CI)
Moon et al/2001[11]	Korea	Coronal	70	60	85.7 (75.7-92.0)	10	14.3 (8.0-24.3)
Basak S, et al./1998[6]	Turkey	Coronal & Axial	182	104	57.1 (49.9-64.1)	78	42.9 (35.9-50.1)
Lannoy-Penisson et al/2007[4]	France	3 views	18	11	61.1 (38.6-79.7)	7	38.9 (20.3-61.4)
McDonald et al/2008[5]	UK	Coronal	76	56	73.7 (62.8-82.3)	20	26.3 (17.8-37.2)
Souza SA, et al/2009[9]	Brazil	Coronal	198	129	65.2 (58.3-71.4)	69	34.9 (28.6-41.7)
Floreani et al./2006[2]	Australia	3 views	44	28	63.7 (48.9-76.2)	16	36.4 (23.8-51.1)
Cankal et al./2004[7]	Turkey	Coronal & Axial	300	252	84.0 (79.4-87.7)	48	16.0 (12.3-20.6)
Simmen et al./2006[3]	Switzerland	3 views	68	44	64.7 (52.8-75.0)	24	35.3 (25.0-47.2)

included racial differences, and differences in AEA investigations and detections by different versions of CT scanners.

The present study revealed that most of AEAs situated between BL/AWEB and BLMT were more localized in the posterior halves of the distance. This finding was similar to our previous 42-half-heads cadaveric study[12] which showed that 97.6% of the AEAs located between both lamellae (BL/AWEB and BLMT), and 85.7% were located in the posterior halves. Studies in western countries also showed that AEAs were mostly situated between these two lamellae and the percentages ranged from 79.3 to 100%[5-6,13-14]. Such high results were also reported from Asia, i.e. 85.5% and 87.2%[9,11].

Stammberger[15] mentioned in his textbook that the AEA usually stays 1 to 2 mm behind the AWEB. However, the mean distance found in this present study was 7.3 mm and such a difference should be noted and recognized by Asian surgeons. Recently, Bortoli et al, from Brazil, reported the study of CT in 300 patients and showed that the average distance from the AEA to the ethmoid bulla was 17.2 mm[16]. The direction of the AEAs from the entrances to the exits was anteromedial and the exits were at the lateral lamella of the cribriform plate[17]. However, our present study showed that a few AEAs ran horizontally.

Localization of the AEAs is important for risk management; sinus surgeons should request CT before any ethmoid sinus surgery. In the past, many studies have suggested other strategies; many measurements have been reported e.g. distances between AEAs and so many points or structures, namely axilla of middle turbinate[19], limen nasi[11], anterior nasal spine[11], inferior turbinate[6], orbital beak and superior oblique muscle[19], the "axilla" formed by the medial and lateral crura of the lower lateral cartilage (superomedial edge of the nostril) in combination with axilla of middle turbinate[18], and nasal beak[20]. However, the accurate measurement during endoscopic sinus surgery may be very difficult to execute under the endoscopic point of view. The BL/AWEB and BLMT are two fixed anatomical structures that the sinus surgeons have to deal with during endoscopic sinus surgery. Some authors suggested localization of AEA based on these two lamellae[3,11,13,14]. We agree with them because our present study showed that most of the AEAs were located between these lamellae and the vast majority (71%) was within the posterior halves (behind mid-point between the BL/AWEB and the BLMT). There were two recent publications on the localization of the AEA by using the suprabullar cells (SBC) as an optional landmark. They found that the AEAs were located within the posterior margin of the SBC[21,22].

Conclusion

Most of the AEAs in Thais located below the skull base and in the posterior half of the distance between the BLMT and the BL/AWEB of the ethmoid bones. The BLMT and the BL/AWEB, which could be demonstrated by multiplayer multislice CT, were two fixed, important landmarks to localize the AEAs during endoscopic sinus surgery.

What is already known on this topic?

The location of the anterior ethmoidal artery was usually mentioned to be just behind the bulla lamella/anterior wall of ethmoid bulla. There has been no study on the locations of the anterior ethmoidal artery in Thais.

What this study adds?

This present study showed that the anterior ethmoidal artery was mostly located below the skull base and between BL/AWEB and BLMT, especially in the posterior half of the distance between the BL/AWEB and the BLMT.

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Potential conflicts of interest

None.

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Vertical basal lamella ของ middle turbinate และ bulla lamella: ตำแหน่งบ่งชี้ที่สำคัญสำหรับหาตำแหน่งของเส้นเลือดแดง anterior ethmoid

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ภูมิหลัง: *เส้นเลือดแดง anterior ethmoid (AEA) เป็นเส้นเลือดที่มีความสำคัญระหว่างการผ่าตัดไซนัสเอธมอยด์ผ่านกล้อง ผู้นิพนธ์ได้ประเมินความชุกของ AEA ที่อยู่ต่ำกว่าฐานกะโหลกศีรษะและหาตำแหน่งของ AEA ที่สัมพันธ์กับโครงสร้างทางกายวิภาคที่คงที่*

วัสดุและวิธีการ: *ใช้ข้อมูลของการถ่ายภาพรังสีซอมพิวเตอร์ของไซนัสในผู้ป่วยจำนวน 100 รายที่ได้รับการถ่ายภาพด้วย 128-multidetector high-resolution CT scanner (Phillips®) โดยถ่ายภาพ thin slice axial CT แล้วสร้างภาพในระนาบ coronal และ sagittal หาตำแหน่งทางเข้าและทางออกจากไซนัสเอธมอยด์ส่วนหน้าของ AEA ประเมินตำแหน่งของ AEA ที่สัมพันธ์กับฐานกะโหลกศีรษะโดยผู้ประเมินสองคน วัดระยะทางระหว่าง AEA และฐานกะโหลกศีรษะ, bulla lamella/ผนังด้านหน้าของ ethmoid bulla (BL/AWEB) และ vertical basal lamella ของ middle turbinate (BLMT)*

ผลการศึกษา: *ร้อยละ 72.5 ของ AEA อยู่ต่ำกว่าฐานกะโหลกศีรษะ ค่าเฉลี่ยของระยะห่างจากฐานกะโหลกศีรษะเท่ากับ 3.2 มิลลิเมตร เกือบทุกรายโดยที่ร้อยละ 95 ของ AEA อยู่ระหว่าง BL/AWEB และ BLMT และร้อยละ 5 ของ AEA อยู่ตรงกับหรือหลัง BLMT ร้อยละ 71 ของ AEA อยู่หลังจุดกึ่งกลางของระยะทางจาก BL/AWEB ถึง BLMT โดยระยะห่างเฉลี่ยจาก BL/AWEB เท่ากับ 7.3 มิลลิเมตร*

สรุป: *AEA ในคนไทยส่วนใหญ่อยู่ต่ำกว่าฐานกะโหลกศีรษะและอยู่ใกล้ BLMT มากกว่า ดังนั้น BL/AWEB และ BLMT ซึ่งเป็นโครงสร้างทางกายวิภาคที่มั่นคง ซึ่งโสตศอนาสิกแพทย์อาจใช้เป็นทางเลือกในการหาตำแหน่งของ AEA*
