Running title:

Anatomy of posterior and middle ethmoidal arteries

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ORIGINAL CONTRIBUTION

Title
Anatomy of the posterior and middle ethmoidal arteries from the view of the endoscopic sinus surgeon.

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SUMMARY

Background: *The anatomy of posterior ethmoidal artery (PEA) and middle ethmoidal artery (MEA) from the view of the endoscopic sinus surgeon is not clear.*

Methodology: *Based on 100 CT images, the anatomical position of the PEA in relation to the posterior ethmoidal cells was classified into five types. Presence of the PEA and MEA, distance from the ethmoid roof, and exposed length in the ethmoid cells were measured. The association of patient's age, sex, MEA presence, and the type of anatomical classification of the PEA with the PEA distance from the ethmoidal roof was analyzed.*

Results: *The PEA position relative to ethmoidal cell walls was mostly around the first wall anterior to the optic canal (92.5%). The PEA distance from the skull base was 0 to 6.4 mm (mean 1.18 mm). MEA was observed in 21% of nasal cavities. The MEA distance from the skull base ranged from 0 to 2.7 mm (mean 1.02 mm). Older age, a longer exposed PEA length in the ethmoid cells, and an absence of MEA were positively associated with a longer distance of the PEA from the skull base.*

Conclusion: *Extra attention is needed when operating on the posterior ethmoid of older patients.*

Key words: Anatomy, Epistaxis, Ethmoid Sinus, Injuries, Skull Base

INTRODUCTION

The anatomy of ethmoidal arteries is of concern to surgeons performing endoscopic sinus surgery as injury to these arteries can cause intraorbital hemorrhage and vision loss [1, 2]. Recognizing the course of ethmoidal arteries with computed tomography (CT) before and during surgery reduces risks of accidental injuries to these structures. Previous studies have been mostly focused on the anterior ethmoidal artery (AEA) but there have been few studies on posterior and middle ethmoidal arteries [1-8]. The exact distances between these ethmoidal arteries and the ethmoidal roof are the surgeons concern.

After branches from ophthalmic artery, the posterior ethmoidal artery (PEA) supplies the dura overlying the planum sphenoidale and mucosa of nasal septum and posterior ethmoid cells [9, 10]. The middle ethmoid artery (MEA), which is present in 31.8% according to a cadaver study [8], exists between the AEA and PEA and supplies the nasal septum and ethmoid cells. The importance of the PEA anatomy is growing with the advancement of surgical procedures. The PEA has to be identified and coagulated for anterior skull base surgery. Recognizing its anatomy during wide sphenoidotomy is important. Compared to the AEA, the PEA exists closer to the optic nerve and coagulation or clipping of PEA is difficult. The anatomy around the PEA is complex and variable. To enable recognition of the PEA anatomy during surgery, identifying the PEA and understanding its relation to ethmoidal cell walls on CT images before operation is necessary. Anatomical variations of the PEA based on patient age and sex are unknown.

To elucidate the PEA and MEA anatomy, we examined CT images and classified the PEA anatomy relative to the ethmoidal cell walls and measured the presence of PEA and MEA, their distance from the ethmoidal roof, and their exposed length in the ethmoid cells. We then tested the hypothesis that the PEA distance from the ethmoidal roof is associated with patient age, sex, presence of MEA, and the PEA anatomical classification.

We indeed found that PEA distance from the skull base was positively associated with advanced age, length of PEA exposed in the ethmoid cells, and the absence of MEA. Special attention is needed in older patients. MEA is present in patients with short PEA distances from the skull base. When examining CT images, attention should be paid to the PEA and MEA, in addition to the AEA.

MATERIALS AND METHODS

Unaffected sinuses from CT images originally taken for the temporal bone were reviewed. This study evaluated CT images including the paranasal sinus region taken at the Department of Otolaryngology Head and Neck Surgery, Jichi Medical University Saitama Medical Center, between April and December 2015.

The exclusion criteria were previous surgery on the sinonasal area, rhinosinusitis, and post-traumatic change. The CT scans of 100 patients were included and the anatomical variations were measured and classified.

Thin slice images (0.5-mm-thick) were taken with CT (Aquilion ONE, Toshiba Medical Systems Corporation, Ohtawara, Japan). Data were processed by three-dimensional DICOM viewer (Ziostation ver. 4.1.7.2; Ziosoft, Tokyo, Japan). All examinations were based on three-dimensional images. The PEA was identified as the first appearing transverse canal on coronal sections viewed in a posterior to anterior manner. The second canal on coronal sections was identified as the MEA if it was not the AEA.

We classified the PEA anatomy into five types depending on its relationship to the ethmoid cell wall. It is not practical to use the anterior wall of the sphenoid sinus because of its variations, i.e. the anterior wall of the sphenoid sinus can exists either anterior to or inside or posterior to the optic canal [(11)]. On sagittal scans, we defined the first wall anterior to the optic canal as the first wall (FW). We classified the PEA position relative to the FW as follows (Fig.1). Type 1; PEA is located posterior to the FW. Type 2; PEA is located inside the FW. Type 3; PEA is located in the ethmoid cell facing the FW posteriorly. Type 4; PEA is located inside the second wall anterior to the optic canal. Type 5; PEA is located anterior to the second wall that is anterior to the optic canal.

Measurement of the PEA distance from the ethmoid roof was based on sagittal sections (Fig. 1,2). The distance was defined as the most prominent portion of the PEA to the skull base. Measurement of the PEA and MEA length exposed in the ethmoid cells were made on coronal sections (Fig. 3). Measurement of the MEA distance from the ethmoid roof was made on sagittal sections (Fig. 4).

Age, sex, PEA anatomical type (Fig. 1), length of PEA exposed in the ethmoid cells and presence of MEA were used as possible factors associated with the PEA distance from the skull base. The relationships between these clinical factors and the PEA distance from the skull base were analyzed with multivariate regression analysis. All statistical analysis data were used by Stata version 14.0 (Stata Statistical Software, College Station, TX). The study was approved by the institutional review board of Jichi Medical University Saitama Medical Center.

RESULTS

CT images of a total of 100 patients (200 sides) were analyzed in this study. The primary diagnosis of the patients were 48 with cholesteatoma, 46 with chronic otitis media, two with otosclerosis, one with sensorineural hearing loss, one with mixed hearing loss, one with extra auditory canal cholesteatoma, and one with external auditory canal tumor. Patient background and measurements are summarized in Table 1.

PEA was present in all nasal cavities. The PEA was mostly located around the FW (Fig. 1, 5). The PEA was rarely present inside or anterior to the second wall anterior to the optic canal. The PEA distance from the skull base ranged from 0 to 6.4 mm (Fig. 6) and was more than 2.0 mm in 24 sides (12%).

The MEA was present in 21% of nasal cavities. The MEA distance from the skull base ranged from 0 to 2.7 mm (Fig. 7) and was more than 2.0 mm in two sides (1%).

Multivariate regression analysis revealed that older age, a longer PEA length exposed in the ethmoid cells, and absence of the MEA were positively associated with a longer PEA distance from the skull base (Table 2). Sex and anatomical type of PEA were not associated with the PEA distance from the skull base.

DISCUSSION

Our study had four major findings. First, we have shown that the PEA was present mostly beside or inside the FW. Second, the PEA distance from the skull base was more than 2.0 mm in 24 sides (12%). Third, MEA was present in 42 sides (21%) and its distance was more than 2.0mm in two sides (1%). Finally, PEA distance from the skull base was positively associated with advanced age, length of PEA exposed in the ethmoid cells, and an absence of the MEA.

To recognize location of ethmoidal arteries during endoscopic endonasal surgery, understanding its relation to surrounding structures, which enables easier identification during endoscopic sinus surgery, is important [1, 12]. We chose the ethmoidal cell walls as the landmark to aid PEA identification as they are easy to identify and are adjacent to the PEA. There are complex anatomical variations around the posterior ethmoid and sphenoid sinus. Onodi cell, defined as the posterior ethmoidal cell which develops laterally and/or superiorly to the sphenoid sinus, is not suitable as a landmark because it is difficult to determine accurately [11]. We used the FW as a landmark to avoid considering the different types of Onodi cell.

The PEA was most commonly present posterior to the FW and runs on the skull base (Fig.1B, Fig.5). The next common type was a PEA that ran inside the FW (Fig. 1C). In total, a PEA running around the FW (Type 1, 2 and 3) was present in 92.5% of nasal cavities. The type of PEA was not associated with its distance from the skull base (Table 2). During surgery, attention should be paid when dissecting the FW.

The rate of floating PEA that was more than 2 mm from the skull base (12%) was similar to that of the AEA based on a previous study. The incidence of floating AEA 2 to 3 mm from the skull base was 10 of 70 cases (14.3%) [1]. However, Cankal et al. reported that the AEA was identified as a separate canal in 84% and PEA was seen as a separate canal in 8% of cases [2]. This huge discrepancy may result from a difference in their study design. Moon et al. used CT and cadaver at the same time, while Cankal et al. used CT with a minimum thickness of 1.0 mm. In our study, we used 0.5 mm slice in a three-dimensional manner. There are more studies on AEA anatomy than on PEA. It has received more focus as the anatomy of the frontal recess is complicated and accidental injury of the AEA is possible during frontal sinus surgery. As the surgeon's skills and knowledge improves and more advanced instruments are developed, more meticulous surgery will be performed. It is possible that meticulous dissection of the FW has not been needed from the point of functional endoscopic sinus surgery, which is aimed at creating a drainage pathway to the sinuses [13]. A recent study showed that

complete removal of ethmoidal cells without any residual lamina reduces risks of recurrent chronic rhinosinusitis [14]. However, in general there has been no data showing the benefit of meticulous surgery compared to functional surgery [15]. Still, meticulous dissection is necessary for endoscopic endonasal skull base surgery, which has been widely performed with the advancement of surgical instruments and surgical techniques [16, 17].

In contrast to the PEA, which was present in all patients, the MEA was detected in only 21% of nasal cavities (Table 1, Fig. 7). The number is similar to the cadaveric study in which MEA was present in 31.8% [8]. When present, the mean distance from the skull base was 1.02 mm and it was close to that of the PEA (1.18 mm) (Table 1). Unlike the PEA, extremely long distances from the skull base was not observed with the MEA (Fig. 6, 7). The MEA distance from the skull base was more than 2.0 mm in two sides. While attention should be paid, the risk of MEA injury may be lower than that of PEA injury.

The PEA distance from the skull base was positively associated with advanced age, length of PEA exposed in the ethmoid cells, and the absence of MEA (Table 2). There was a significant association between PEA distance from the skull base and advanced age (Fig. 8). The reasons for this association is not clear but a possible explanation would be bone remodeling with aging and environmental factor differences between generations. Special attention is needed when performing endoscopic sinus surgery for older patients.

The length of PEA exposed in the ethmoid cells was positively associated with the PEA distance from the skull base (Fig. 9). In patients where the distance between the orbit and nasal septum is long, the length of exposed PEA is longer. This applies to the MEA as well. Attention is needed when doing surgery with well-pneumatized ethmoid cells.

Existence of MEA was negatively associated with PEA distance from the skull base. The MEA and PEA supply the nasal septum and ethmoid cells. The blood supply by MEA reduces the flow of PEA. When PEA distance from the skull base is short, the surgeon should pay attention to the presence of the MEA.

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AUTHORSHIP CONTRIBUTION

HY performed the measurements. HY, KN conceived and designed the study. HY, KN, YE, SM, HK analyzed the data. HY, KN, HH, YK and NY wrote the manuscript.

CONFLICT OF INTEREST

The authors report no conflicts of interest.

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FIGURE LEGENDS

Fig. 1

Classification of PEA anatomical position. A, PEA position was classified into five types relative to the first wall anterior to the optic canal (FW). B, Type 1. PEA is present between the optic canal and FW. C, Type 2. PEA is present inside the FW. D, Type 3. PEA is present between the FW and second wall anterior to the optic canal. E, Type 4. PEA is present inside the second wall. F, Type 5. PEA is present anterior to the second wall. FS, frontal sinus; FW, first wall anterior to the optic canal; OC, optic canal; P, pituitary gland; 1 to 5, Types; arrows, first wall anterior to the optic canal; arrow heads, PEA.

Fig. 2

Measurement of PEA distance from the skull base. A, sagittal CT scan without annotation. B, Bar indicates the measured distance.

Fig. 3

Measurement of PEA length exposed in the ethmoid cells. A, coronal CT scan without annotation. B, Bar indicates the measured length.

Fig. 4

Measurement of MEA distance from the skull base. A, sagittal CT scan without annotation. B, Bar indicates the measured distance. AEA, anterior ethmoidal artery; PEA, posterior ethmoidal artery.

Fig. 5

Frequency of each anatomical type of posterior ethmoidal artery based on Fig. 1.

Fig. 6

Posterior ethmoidal artery (PEA) distance from the skull base.

Fig. 7

Middle ethmoidal artery (MEA) distance from the skull base. MEA was absent in 79% of nasal cavities.

Fig. 8

Scatter graph of posterior ethmoidal artery (PEA) distance from the skull bases vs. age with fitted line. There was a positive association between distance and advanced age.

Fig. 9

Scatter graph of posterior ethmoidal artery (PEA) distance from the skull bases vs. PEA length exposed in the ethmoid cells with fitted line. There was a positive association between PEA distance from the skull base and its exposed length in the ethmoid.

Table 1. Patients' background and anatomical measurements

	Mean (SD)	N (%)
Age (years)	55.4 (16.6)	
Sex		
Male		50 (50)
Female		50 (50)
PEA		
Existence		200 (100)
Distance from skull base (mm)	1.18 (1.00)	
lenghth exposed in the ethmoid (mm)	5.96 (2.48)	
MEA		
Existence		42 (21)
Distance from skull base (mm)	1.02 (0.55)	
lenghth exposed in the ethmoid (mm)	3.87 (1.74)	

Table 2. Multiple regresson analysis of factors associated with a longer PEA distance from the skull base

	Coef.	p	95%CI		
Age	0.01	0.007	0.00	-	0.02
Sex (male)	-0.21	0.118	-0.48	-	0.05
Type of PEA	-0.03	0.540	-0.14	-	0.07
Length of PEA	0.14	<0.001	0.08	-	0.19
Existence of MEA	-0.34	0.040	-0.66	-	-0.02
Constant term	0.00	0.990	-0.61	-	0.60

Coef, regression coefficient; CI, confidence interval; PEA, posterior ethmoidal artery; MEA, middle ethmoidal artery