Computed Tomographic Exploration of the Middle Ethmoidal Artery

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Abstract

Keywords

- ▶ middle ethmoidal artery
- ▶ ethmoid
- ▶ accessory
- ▶ endoscopic skull base surgery
- ▶ endoscopy
- ▶ radiology
- ▶ skull base
- ▶ anterior skull base
- ▶ endoscopic sinus surgery

Objectives The integral involvement of sinus and skull base surgeries in the field of otolaryngology makes the endonasal vasculature including the ethmoidal arteries important to consider. The anterior ethmoidal artery (AEA) and posterior ethmoidal artery (PEA) are well-known entities, yet the relatively recent notion of accessory or middle ethmoidal vessels complicates our understanding of this arterial system.

Study Design Radiographic study.

Methods Fifty computed tomographic angiographies were studied for the presence of accessory/middle ethmoidal arteries (MEAs). If contrasted arteries were not visualized reliably, foramina were accepted as evidence of arteries. The accessory arteries/foramina were then compared with the locations of the AEA and PEA.

Results A total of 19 of the 50 patient samples studied had evidence of a right, left, or bilateral middle ethmoidal vessels (38%). Overall, 26 arteries total were identified out of the 100 sides (26%). Unilateral middle arteries were more common than bilateral, and right sided were more common than left. There was no evidence of multiple MEAs on a given side.

Conclusion The endonasal surgeon must be cognizant of the possible presence of MEAs. These arteries should be considered when working in the medial orbit and anterior skull base region.

Introduction

Endonasal surgery is a cornerstone in the field of otolaryngology. The advent of the rod-lens endoscope allowed surgeons to access and manage lesions of the paranasal sinuses and nasal cavity. More recently, these endonasal approaches have been extended beyond the sinuses and into the cranial base. These approaches require corridors adjacent to critical cranial structures.¹ Surgical approaches are becoming more refined, yet a considerable challenge in endoscopic endonasal surgery is gaining an understanding of the complex, variable,

and often subtle anatomy involved. Inadvertent injury to neural and vascular structures can hinder the surgical team's view and result in significant morbidity to the patient.² There has been research and progress in developing best practices if vascular injury should arise, yet prevention of such injuries remains a goal.³

Vascular variation in human anatomy is historically abundant. In a field that requires significant preoperative planning, questions arise when encountering unanticipated structures. The anterior ethmoidal artery (AEA) and posterior ethmoidal artery (PEA) are commonly utilized as landmarks during

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Fig. 1 Coronal computed tomography angiography image exemplifying right and left anterior ethmoidal foramina.

endonasal access to the anterior skull base encountered during sinonasal surgery. Each ethmoidal artery exits the orbit through individual foramina in the medial wall of the orbit, near the ethmoid roof. In addition, their course is frequently variable in terms of origin and distribution. This variation, and the fact that no clear and reliable landmarks are available to locate the arteries, creates risk for iatrogenic damage that can result in bleeding and hematoma, compromise to the nasal vasculature, and blindness.^{4,5} In addition, ethmoidal vessels are often intentionally ligated to treat compression syndromes such as anterior ethmoidal nerve syndrome and optic nerve compression, as well as for the treatment of epistaxis.^{6–8} As such, understanding ethmoidal arterial anatomy is very important.

Adding to the complexity of the ethmoid arterial system, middle ethmoid arteries (MEAs) can be encountered and have been discussed in previous studies.^{8–11} As described, MEAs are variably present and enter the nasal cavity via individual foramen in the ethmoid bone between the anterior and posterior ethmoidal arteries. Their prevalence, course, and distribution are still undefined. This study aims to further the current research by analyzing and quantifying the presence of MEAs in a computed tomography (CT) study.

Methods

Data collection was performed on the computer program Osirix (Pixmeo, Switzerland) utilized on the Macintosh OS. This open-source Digital Imaging and Communications in Medicine (DICOM) viewer allows for the manipulation and study of CT compilations. Fifty separate de-identified patient computed tomography angiographies (CTAs) were chosen for analysis from a database reviewed by the internal review board.

Samples were analyzed for the presence of MEAs on both the right and left sides, totaling 100 sides. Both the anterior and posterior ethmoidal foramina and/or their respective arteries were located in the coronal, sagittal, or axial planes, depending on which view provided the best recognition (►Fig. 1 and 2). The sample was then examined for the presence of MEAs or middle ethmoid foramina as an indication of an artery. Once an accessory artery or foramen was located in a given plane, two-dimensional (2D) orthogonal viewing allowed for its identification in all planes as shown in ►Fig. 3. The incidence was recorded, along with laterality. To study MEA localization, the distance between the identified MEAs and both the posterior and anterior ethmoidal

Fig. 2 Two-dimensional orthogonal image of a right posterior ethmoidal foramen. The foramen is located at the center of the crosshairs in the coronal, axial, and sagittal images.

Fig. 3 Two-dimensional orthogonal image showing a left middle ethmoidal foramen in the coronal and sagittal images, and a left middle ethmoidal artery in the axial image. The arrows denote the foramina or artery.

arteries was measured with Osirix. To further complement the study, a three-dimensional rendering was computed from the CTA data to represent the locations of the ethmoidal foramina, including the middle ethmoidal foramen, within the orbital wall (**►Fig. 4**) and the anterior cranial fossa floor (**►Fig. 5**).

Results

In the 50 CT samples analyzed, 19 had unilateral or bilateral MEAs or foramina (38%). Twenty-six MEAs were present in 100 total sides (26%). Unilateral MEAs were more common (12 of 19 = 63%) than bilateral (7 of 19 = 37%). Right MEAs were significantly more frequent (17 of 26 = 65%) than left MEAs (9

of 26 = 35%). We did not encounter any evidence of multiple foramina or accessory vessels on a single side. For the nine left-sided MEAs, the average distance between the MEA and the AEA and PEA was 11.77 ± 2.09 mm and 11.40 ± 2.34 mm, respectively. For the 17 MEAs found on the right, the distance between the MEA and AEA was 10.80 ± 3.13 mm; the MEA and PEA distance was 11.21 ± 3.57 mm (**►Table 1**).

An ethmoidal foramen was significantly easier to identify than the contrasted vessel. This was true for all vessels (anterior, middle and posterior). As shown in our figures, the small vessels of the orbit were difficult to discern, making reliable identification of actual contrasted ethmoidal arteries impossible. Arbitrarily, we decided to interpret bony foramina as evidence for a middle ethmoidal vessel. During data

Fig. 4 Three-dimensional reconstruction of a patient computed tomography angiography sample showing the anterior, middle, and posterior ethmoidal foramina in the medial wall of the left orbit as indicated by the arrows.

Fig. 5 Three-dimensional reconstruction of a patient computed tomography angiography sample with partial removal of the frontal bone. The arrows denote the locations of the left anterior, middle, and posterior ethmoidal foramina in the floor of the anterior cranial fossa.

Table 1 Analysis of distances between the middle ethmoidal artery and the anterior and posterior ethmoidal arteries

	Right side AEA to MEA, mm	Right side PEA to MEA, mm	Left side AEA to MEA, mm	Left side PEA to MEA, mm
Average	10.84	11.21	11.77	11.40
Standard deviation	3.13	3.57	2.10	2.34
Confidence	1.49	1.70	1.37	1.53
Confidence interval	9.31–12.32	9.51–12.91	10.40–13.14	9.90–12.90

Abbreviations: AEA, anterior ethmoid artery; MEA, middle ethmoid artery; PEA, posterior ethmoid artery.

collection, the coronal plane seemed to be most conducive to identifying and locating the foramina. Once located coronally, however, their identification became easier in any plane with a 2D orthogonal view (► **Figs. 6–8**).

Discussion

The ethmoidal arteries arise from the orbital vessel system and are a critical vascular supply to the nasal cavity and median anterior skull base. The ethmoidal arteries arise individually from the ophthalmic artery near the medial wall of the orbit. The PEA and AEA penetrate the nasal cavity through their own foramen, near the crista galli and cribriform plate, along with a vein and nerve with the same name. Upon entering the cranium, each divides into a branch that

supplies the dura mater and a branch that descends through channels in the floor of the anterior cranial fossa. Within the nasal cavity the vessels further divide into a lateral branch supplying the lateral ethmoid sinuses mucosa and a medial branch supplying the nasal septum. These arteries comprise significant anastomoses, their branches joining with main arterial conduits such as the sphenopalatine artery and branches of the maxillary and facial arteries. As such, the ethmoidal vessels are an important component of the nasal vascular system and located in potentially dangerous and important locations in the context of endonasal and skull base surgery.

Although not commonly recognized in discussions of anatomy, evidence of accessory or MEAs has been previously documented. Several authors have provided evidence of

Fig. 6 Coronal computed tomography angiography image exemplifying bilateral middle ethmoidal foramina in a patient.

Fig. 7 Axial computed tomography angiography compilation showing the locations of the anterior, middle, and posterior ethmoidal foramina (from left to right). These images represent a single patient.

Fig. 8 Coronal computed tomography angiography compilation showing the locations of the anterior, middle, and posterior ethmoidal foramina (from top to bottom). These images represent a single patient.

accessory vessels between the AEA and PEA. Vatanasapt et al⁸ described “tertiary” ethmoid arteries in 36% of specimens in an analysis of sinus vasculature arising from the orbit. Similarly, Takahasi et al¹⁰ demonstrated accessory ethmoidal foramina in 18 of 54 orbits in their study of medial orbit anatomy (33.3%). In an article published in 2011 analyzing ethmoidal foramina, Mutalik et al¹¹ found that 35 sides of 100 skulls analyzed had right middle ethmoidal foramina; 41 of 100 skulls had middle foramina on the left. In these publications and most others on the subject, the presence of an accessory vessel has mostly been inferred by the identification of a middle foramen or foramina.⁹ More recently, Wang et al⁹ documented the existence of actual ethmoidal vessels in preserved cadavers. They located 14 MEAs in 22 specimens

studied, with a 31.8% incidence among the 44 sides. The results in these studies are significant; however, there is still limited data on MEAs and a variety of adopted nomenclature. As such, a uniform system for classification has yet to be established.

Ethmoidal vessels became critical to consider with the adoption of paranasal sinus, skull base, and orbital surgery. Due to their location within the nasal mucosa, iatrogenic damage is a risk. Maxillectomies involve significant resection on the lateral wall of the nasal cavity, and controlled ligation must often be performed. Ethmoidectomies for the treatment of inflammatory disease or tumors also present risks to the vasculature. Fortunately, major complications of sinus surgery related to vessel compromise, such as blindness and

hemorrhage, are generally rare.¹² However, serious complications can occur. One of the more frequent major complications is a retrobulbar hematoma or hemorrhage. This can result in a compartment syndrome that causes ischemia of the optic nerve. Complications involving ethmoidal vessels in sinus surgery generally seem attributable to variation in their course and location; therefore, they are potentially prevented by a thorough understanding of the vasculature.^{13,14}

In addition to their relevance as potential complications of endonasal surgery, the ethmoidal arteries are directly tackled during other procedures such as ligation or cauterization to control severe epistaxis when conservative measures have failed.^{7,15} A refractory case could implicate an accessory vessel.

In recent decades, endoscopic sinus surgery has expanded beyond the paranasal sinuses into the skull base. Using systematic endoscopic endonasal approaches, surgeons have been able to access a wide variety of lesions in historically complex skull base locations.¹ In appropriately selected patients, these approaches have resulted in a significant decline in overall morbidity and mortality when compared with external approaches.^{1,2,16} Understanding of the methods, pertinent anatomy, and potential pitfalls may improve patient outcomes.

Approaches to the ventral skull base present an additional opportunity to encounter the ethmoidal arteries. An endoscopic endonasal transcribriform approach to the anterior cranial fossa involves a craniotomy in the region of the ethmoidal arteries, depending on location of pathology.¹⁷ In these cases, ligation of the ethmoidal vasculature is indicated to avoid hemorrhage and hematomas in critical locations.⁹

As mentioned earlier, the anatomy of the ethmoidal artery system has been the subject of previous research; however, it remains variable and complicated.^{5,18} The potential presence of MEAs further complicates our understanding of this vascular system.

Data collected in this study compare well with current literature on the subject.^{8–12} Our data suggest that in 38% of the patients, one might encounter an accessory vessel. This number is significant, especially when considering the potential complications of encountering unanticipated vasculature. However, a major limitation of this study is the utilization of foramina as an indication of an artery. Possibly due to the size of the vessels involved, the ethmoidal and orbital arterial systems were undercontrasted in our CTAs; thus they were especially difficult to visualize within a foramen. As such, although this study was able to clearly demonstrate bony landmarks, the imaging was inadequate to define the course of any artery beyond their relative foramina. It may be useful in future studies to use magnetic resonance imaging with contrast to highlight vasculature more clearly and define the course or origin of the ethmoidal arteries.

Despite its shortcomings, this study is still useful in the context of intranasal surgery. The frequency of MEAs should encourage surgeons to consider the possibility of encountering accessory vessels when performing surgery in the region. The accessory foramen or vessel was often located roughly

halfway between the anterior and posterior ethmoidal vessels. Furthermore, the AEA and PEA were found consistently in roughly the same location, the PEA toward the apex of the orbit and the AEA roughly horizontal to the crista galli. Accessory vessels were located neither posterior to the posterior artery nor anterior to the anterior artery, giving credence to the labeling of “middle” arteries. In addition, the distance measurements between accessory vessels and the AEA and PEA were similar on both the right and left at roughly 11 mm, although it was rarely located at the midpoint. The AEA is relatively easy to identify due to its superficial location within the nasal cavity. It is often located at, immediately anterior, or immediately posterior to the basal lamella.⁵ After AEA localization, our distance measurements can help the surgeon locate possible accessory ethmoidal vessels. These parameters could provide a sort of mental framework for the surgeon and may lend to a careful systematic approach when attempting to locate middle arteries.

In addition, our study should provide impetus for further research because the existence of these vessels has yet to be universally considered. Even more limited is direct evidence of the existence of these vessels. More studies are needed to quantify reliably how often they may be encountered and to provide a thorough understanding of their clinical relevance.

Conclusions

The existence of MEAs is clinically relevant to current practices in endonasal surgery. The advent of endoscopic cranial base surgeries increases the involvement of these arteries, and sinus and endonasal orbital surgeries are still frequently utilized to address pathology. Increased knowledge of this arterial system will help prevent complications and further refine patient outcomes.

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References

- 1 Snyderman CH, Pant H, Carrau RL, Prevedello D, Gardner P, Kassam AB. What are the limits of endoscopic sinus surgery?: the expanded endonasal approach to the skull base. *Keio J Med* 2009;58(3): 152–160
- 2 Solari D, Villa A, De Angelis M, Esposito F, Cavallo LM, Cappabianca P. Anatomy and surgery of the endoscopic endonasal approach to the skull base. *Transl Med UniSa* 2012;2:36–46
- 3 Valentine R, Wormald PJ. Controlling the surgical field during a large endoscopic vascular injury. *Laryngoscope* 2011;121(3): 562–566
- 4 Yang YX, Lu QK, Liao JC, Dang RS. Morphological characteristics of the anterior ethmoidal artery in ethmoid roof and endoscopic localization. *Skull Base* 2009;19(5):311–317
- 5 Han JK, Becker SS, Bomeli SR, Gross CW. Endoscopic localization of the anterior and posterior ethmoid arteries. *Ann Otol Rhinol Laryngol* 2008;117(12):931–935
- 6 Shalom AS. The anterior ethmoid nerve syndrome. *J Laryngol Otol* 1963;77:315–325

- 7 Solares CA, Luong A, Batra PS. Technical feasibility of transnasal endoscopic anterior ethmoid artery ligation: assessment with intraoperative CT imaging. *Am J Rhinol Allergy* 2009;23(6): 619–621
- 8 Vatanasapt P, Thanaviratnanich S, Chaisiwamongkol K. Landmark of ethmoid arteries in adult Thai cadavers: application for sinus surgery. *J Med Assoc Thai* 2012;95(Suppl 11):S153–S156
- 9 Wang L, Youseef A, Al Qahtani AA, et al. Endoscopic anatomy of the middle ethmoidal artery. *Int Forum Allergy Rhinol* 2014;4(2): 164–168
- 10 Takahashi Y, Kakizaki H, Nakano T. Accessory ethmoidal foramina: an anatomical study. *Ophthal Plast Reconstr Surg* 2011;27(2): 125–127
- 11 Mutalik A, Kolagi S, Hanji C, Ugale M, Rairam GB. A morphometric anatomical study of the ethmoidal foramina on dry human skulls. *J Clin Diagn Res.* 2011;5(1):28–30
- 12 Stankiewicz JA. Complications of endoscopic intranasal ethmoidectomy. *Laryngoscope* 1987;97(11):1270–1273
- 13 Klenk G. Blindness caused by retrobulbar hemorrhage (orbital compartment syndrome) [in Hungarian]. *Orv Hetil* 2010;151(38): 1537–1544
- 14 Han JK, Higgins TS. Management of orbital complications in endoscopic sinus surgery. *Curr Opin Otolaryngol Head Neck Surg* 2010;18(1):32–36
- 15 Asanau A, Timoshenko AP, Vercherin P, Martin C, Prades JM. Sphenopalatine and anterior ethmoidal artery ligation for severe epistaxis. *Ann Otol Rhinol Laryngol* 2009;118(9):639–644
- 16 Gendeh BS. Expanded endoscopic endonasal approach to anterior and ventral skull base: an evolving paradigm. *ISRN Endoscopy*. <http://www.hindawi.com/journals/isrn/2013/149841/cta/>
- 17 Liu JK, Eloy JA. Expanded endoscopic endonasal transcribriform approach for resection of anterior skull base olfactory schwannoma. *J Neurosurg* 2012;32(Suppl):E3
- 18 Erdogmus S, Govsa F. The anatomic landmarks of ethmoidal arteries for the surgical approaches. *J Craniofac Surg* 2006; 17(2):280–285