Commentary on:
Anterior and Posterior Ethmoidal Artery Ligation in Anterior Skull Base Meningiomas: A Review on Microsurgical Approaches
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Surgical Anatomy for Control of Ethmoidal Arteries During Extended Endoscopic Endonasal or Microsurgical Resection of Vascular Anterior Skull Base Meningiomas

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Meningiomas represent about 13%–20% of brain tumors; skull base meningiomas represent about 44%. Anterior skull base meningiomas are supplied from anterior or posterior ethmoidal arteries (branches of the ophthalmic artery), as in olfactory groove (10%) and tuberculum sellae and planum sphenoidale (13%) meningiomas, or middle meningeal arteries, as in sphenoid ridge meningiomas 17% (9, 13, 23). In addition to anastomosis between the middle meningeal artery and the ophthalmic artery, the middle meningeal artery may arise from the ophthalmic artery, or the ophthalmic artery may arise from the middle meningeal artery in rare cases (11, 12, 15, 33). Collaterals from the meningeal branches of the internal carotid arteries, frontal or sphenoid branches of the middle meningeal arteries, and the sphenopalatine branch of the distal maxillary artery may share in the secondary arterial supply of midline anterior skull base meningiomas (olfactory groove, planum sphenoidale, and tuberculum sellae). This rich arterial network predisposes anterior skull base lesions to high vascularity in many cases, especially meningiomas and arteriovenous malformations.

Anterior skull base meningiomas may be approached through transcranial (bicoronal subfrontal, oblique subfrontal, interhemispheric, or classic pterional transsylvian approaches) or extended endonasal minimally invasive approaches. Operating in a less vascular field may be achieved if the feeding anterior and posterior ethmoidal arteries are controlled preoperatively or early during the operation (29). Hypertrophied feeding ethmoidal vessels passing through sclerosed foramina are difficult to control early in the setting of edematous brain or a huge tumor with difficult retraction during open transcranial microsurgery. The vessels may be hard to control during an endoscopic transnasal approach when they are embedded in hyperostotic sclerosed bone. They may be better controlled intracranially or extracranially via microsurgical or endoscopic approaches rather than with endovascular embolization, which carries a risk of blindness induced by retrograde spilling of embolization material onto the ophthalmic arteries, which are the main stems of the ethmoidal vessels.

Anterior skull base meningiomas, especially olfactory groove meningiomas because of their subfrontal origin, usually reach huge sizes before symptoms attract the attention of a keen treating physician in many developing and developed countries. Chemotherapy so far is futile (19, 20, 25). Large tumors usually parasitize additional blood supply from neighboring arteries. At this stage, surgical extirpation is the only option if the tumors have grown beyond the critical radiosurgical limiting size (17). A major challenge for successful resections of these meningiomas, whether using open microsurgical or endoscopic approaches, is the proper control of the arterial supply through the anterior or posterior ethmoidal arteries. Most studies have shown wide anatomic and radiologic aberrations of the ethmoidal arteries, such as passing over the roof of the frontal recess or the posterior ethmoidal sinus, together with lamellar variability and possible incoherence that may hinder the surgeon's ability to identify the artery. In suspected highly vascularized anterior basal meningiomas, digital subtraction angiography is required together with computed tomography (CT) angiography before embarking on embolization or operation.

Manjila et al. (14) studied the anatomic variations of the ethmoidal foramina in anthropology specimens. They used

Keywords
- Anterior skull base meningioma
- Arterial ligation
- Meningioma
- Olfactory groove meningioma

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
CT: Computed tomography

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a Lynch or transcaruncular approach in 3 patients as safe feasible approaches for control of these vessels before open or endoscopic resection of meningiomas that did not receive embolization or received only partial embolization. The duration between embolization and surgery is not yet standardized to avert reopening of arteries that received embolization and the formation of new vasculature, which may neutralize the embolization effect (7, 18). Preoperative embolization of highly vascular anterior cranial fossa meningiomas is feasible but is not without hazards, including ophthalmic artery iatrogenic extension of embolization (21, 22). Thorough knowledge of the microsurgical and endoscopic anatomy of ethmoidal arteries and possible safe clipping sites is a prerequisite for proper selection of the surgical approach and surgical planning and safe execution of complete removal. The success of surgery substantially depends on the surgeon's intelligent choice of a familiar approach for a particular tumor site and blood supply. Unnecessarily occluding bridging and drainage veins might be catastrophic.

The posterior ethmoidal artery arises from the proximal first segment of the ophthalmic artery. Arising from the distal intraorbital third segment of the ophthalmic artery, the anterior ethmoidal arteries penetrate the lamina papyracea, into the roof of the ethmoid sinuses where it gives off its dorsal nasal artery and through the cribriform plate close to the crista galli to the intracranial opening of the anterior ethmoidal canal to form the anterior falx artery (14). In a cadaver study (3), the anterior ethmoidal foramen was about 32 mm to the right of the middle point of the nasofrontal suture and 34 mm to the left. It was 12.3 mm anterior to the posterior foramen, which was 7.1 mm more anterior to the distal opening of the right optic canal and 7.3 mm on the left. In an anatomic endoscopic study (1), the posterior ethmoidal artery was a mean 11.08 mm (range, 8–16 mm) anterior to the optic canal, whereas the anterior ethmoidal artery was a mean 13 mm (range, 10–17 mm) more anterior to the posterior ethmoidal artery. It was mainly found between the superior and middle lamellae (1, 3). In an endoscopic study in Chinese adults, the distance from the columella to the anterior ethmoidal artery measured 62.71 mm $\pm$ 2.18 on the right side and 63.38 mm $\pm$ 1.69 on the left. The distance between the columella and the posterior ethmoidal artery was 70.91 mm $\pm$ 1.99 on the right and 71.79 mm $\pm$ 1.95 on the left (10).

The right posterior ethmoidal artery diameter was 0.66 mm $\pm$ 0.21, and the left posterior ethmoidal artery diameter was 0.63 mm $\pm$ 0.19. The anterior ethmoidal arteries were generally thicker than the posterior ethmoidal artery (0.92 mm $\pm$ 0.2 on the right and 0.88 mm $\pm$ 0.15 on the left) (8). In another study, the diameter of the anterior ethmoidal artery was 6–10 mm (32). The anterior ethmoidal artery runs between the second and third lamellae (where it is identified endoscopically at least in 90% of cases) or through the suprabulbar recess to the anterior ethmoidal canal with the anterior ethmoidal nerves and veins (8, 22, 27, 32). The anterior ethmoidal arteries are always single. They were absent in 2 of 30 sides. In such cases, the posterior ethmoidal arteries ran anteriorly and interiorly divided through the crista galli suture to supply the anterior ethmoidal territory. The persistently present anterior ethmoidal canal was 7–10 mm in length and was dehiscent in its proximal or distal part in one third of cases.

During endoscopic exposure, the surgeon may localize the artery parallel to the ethmoid sinus roof, as it curves along the cribriform plate posterolateral to anteromedial at an angle of 60° to the lamina papyracea. It may be found in the roof of the frontal recess or the roof of the posterior ethmoid sinus in a few cases. A 30° rigid endoscope is preferred for clipping or a curved Ligaclip with 0° scope. It is more accessible in a well-pneumatized sinus (32). It is recommended to assess ethmoid pneumatization by CT to decrease the risk of injuring the artery (27). Minimally invasive extended endonasal approaches allow early control of the feeding ethmoidal arteries. However, these endoscopic approaches are demanding and require sharpened surgical skill and an adequate learning curve to minimize postoperative complications (9).

Visualization of the lamina papyracea in the medial orbital wall allows the anterior ethmoidal foramina and canal to be identified for safe early coagulation and division of the anterior ethmoidal arteries extracranially. The anterior ethmoidal artery is sought posterior to the anterior face of the ethmoidal bulla. The smaller posterior ethmoidal artery is looked for at the junction of the roof of the sphenoid and posterior ethmoid sinus. White et al. (31) recognized 3 safe sites for control of the anterior ethmoidal artery before resection in the presence of a vascular anterior skull base lesion through a single flap fronto-orbital craniotomy instead of the classic pterional or subfrontal approaches: 1) the anterior ethmoidal foramen at the lamina papyracea of the medial orbital wall, 2) the anterior ethmoid canal at the lateral ethmoid wall, and 3) intracranial extradural at the cribriform plate. The open lamina papyracea clipping site was previously described in a bicoronal intracranial extradural approach (16).

Extracranial open bilateral anterior and posterior ethmoidal artery ligation may be performed through Lynch incision exposure down to the periosteum of the medial orbital walls. The frontoethmoidal suture is followed bluntly for about 22 mm posterior to the lacrimal crest, and the posterior ethmoidal artery is encountered about 15 mm posterior to the anterior ethmoidal artery (14). The extracranial transcaruncular approach entails an incision just lateral to the caruncle, identifying the lacrimal fossa and following the avascular facial plans posteromedially to the frontoethmoidal suture. The periosteum is incised bilaterally to allow a posterior subperiosteal dissection trajectory to the anterior ethmoidal arteries.

In a paper recently published in **WORLD NEUROSURGERY**, the authors reviewed microsurgical anatomy literature pertinent to extracranial ligation of the anterior and posterior ethmoidal arteries and identified 2 possible control sites. They applied their findings in 5 approaches during exposure of anterior cranial fossa basal meningiomas. The results apply to an endoscopic rather than an open approach, although both may be used interchangeably (26). Early arterial ligation is an added advantage in endoscopic transnasal approaches to anterior skull base meningiomas (29). The frontal recess, the anterior ethmoidal artery, and the posterior ethmoidal artery were suggested as constant landmarks in the extended endoscopic transnasal approach to the anterior skull base (32). The authors preferred endoscopic approaches, which are more amenable to small or medium-sized lesions at the present stage of surgical expertise. Schroeder (24) found no advantage of an endoscopic approach over craniotomy in surgery of small or