Anatomic Nuances of the Ophthalmic Artery Origin from a Ventral Viewpoint: Considerations and Implications for Endoscopic Endonasal Surgery

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BACKGROUND: The origin of the ophthalmic artery is within the surgical field of endoscopic endonasal approaches (EEAs) to the suprasellar and parasellar regions. However, its anatomy from the endoscopic point-of-view has not been adequately elucidated.

OBJECTIVE: To highlight the anatomy of the ophthalmic artery origin from an endoscopic endonasal perspective.

METHODS: The origin of the ophthalmic artery was studied bilaterally under endoscopic visualization, after performing transplanum/transtubercular EEAs in 17 cadaveric specimens (34 arteries). Anatomic relationships relevant to surgery were evaluated. To complement the cadaveric findings, the ophthalmic artery origin was reviewed in 200 "normal" angiographic studies.

RESULTS: On the right side, 70.6% of ophthalmic arteries emerged from the superior aspect, while 17.6% and 11.8% emerged from the superomedial and superolateral aspects of the intradural internal carotid artery, respectively. On the left, 76.5%, 17.6%, and 5.9% of ophthalmic arteries emerged from the superior, superomedial, and superolateral aspects of the internal carotid, respectively. Similar findings were observed on angiography. All ophthalmic arteries emerged at the level of the medial opticocarotid recess. Overall, 47%, 26.5%, and 26.5% of ophthalmic arteries (right and left) were inferolateral, inferior, and inferomedial to the intracranial optic nerve segment, respectively. On both sides, the intracranial length of the ophthalmic artery ranged from 1.5 to 4.5 mm (mean: 2.90 ± standard deviation of 0.74 mm).

CONCLUSION: Awareness of the endoscopic nuances of the ophthalmic artery origin is paramount to minimize the risk of sight-threatening neurovascular injury during EEAs to the suprasellar and parasellar regions.

KEY WORDS: Anatomy, Endoscopic endonasal approach, Medial opticocarotid recess, Ophthalmic artery, Skull base

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During the final 2 decades of the last century, the introduction of rigid endoscopes revolutionized the fields of otolaryngology-head and neck surgery and neurosurgery.[1-5]

Currently, the endoscopic endonasal approach (EEA) is considered the standard for the management of appropriately selected suprasellar and parasellar lesions, such as craniopharyngiomas and tuberculum sellae meningiomas. By making use of the endonasal corridor, EEA avoids brain retraction and provides a direct visualization of the suprasellar cisterns, and of surrounding neurovascular structures. In addition, unlike during transcranial approaches, early tumor devascularization and decompression of the optic apparatus can be accomplished.[3-6] Nonetheless, approaches to the suprasellar region have a steep learning curve, and must avoid injury to major neurovascular structures within the surgical field, such as the internal carotid artery (ICA), ophthalmic artery,

ABBREVIATIONS: DDR, distal dural ring; **EEA,** endoscopic endonasal approach; **ICA,** internal carotid artery; **LOCR,** lateral opticocarotid recess; **MOCR,** medial opticocarotid recess

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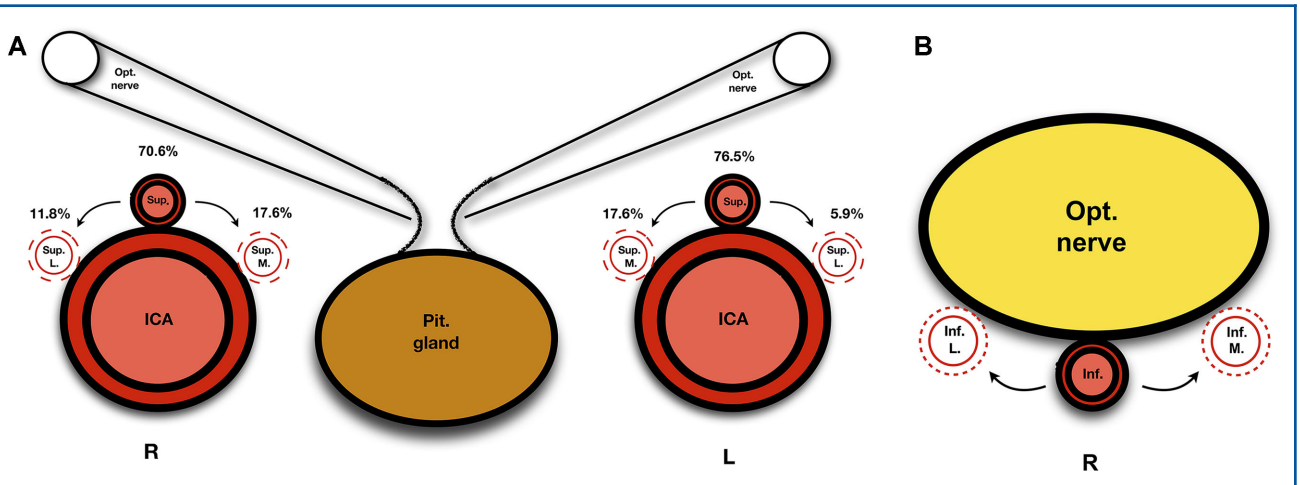


FIGURE 1. *Schematic diagrams illustrating* **A**, *the origin of the ophthalmic artery from the ICA and* **B**, *its position relative to the intracranial optic nerve segment. The percentages for each position of origin from the ICA are shown. ICA, internal carotid artery; Inf, inferior ophthalmic artery position; Inf. L., inferolateral ophthalmic artery position; Inf. M., inferomedial ophthalmic artery position; Opt. nerve, optic nerve; Pit. gland, pituitary gland; Sup., superior ophthalmic artery origin; Sup. L., superolateral ophthalmic artery origin; Sup. M., superomedial ophthalmic artery origin.*

optic chiasm, and optic nerve.[7-9] Therefore, endoscopic skills and anatomic knowledge are imperative for the performance of a safe and successful surgery.[3-8]

Although the microsurgical anatomy of the intracranial segment of the ophthalmic artery is well-documented,[10-12] the literature concerning its anatomy from a ventral (ie, endoscopic endonasal) viewpoint is limited.[13-15] Moreover, recent additions to the literature, such as the introduction of a ventral-based classification of the ICA[16] and the definition of the endonasal anatomy of the optic canal,[14] warrant an updated description of the origin of the ophthalmic artery.

This study sought to further define the anatomy of the origin of the ophthalmic artery as seen from the EEA perspective, with particular emphasis on its relationship with the ICA, the medial opticocarotid recess (MOCR) and optic nerve. Though regardless of the skull base approach, knowledge of the anatomy of the ophthalmic artery is important, a thorough understanding is essential before EEAs to the suprasellar region are undertaken.[2-4,14-22]

METHODS

The origin of the ophthalmic artery of 17 latex-injected cadaveric specimens (34 arteries) was studied under endonasal endoscopic visualization. This study received an institutional review board exemption because the dissections were performed on deidentified cadaveric specimens. All dissections were carried out in full adherance with regulations governing the use of human cadaveric tissues at our institution.

In each cadaveric specimen, a transplanum/transtuberculum EEA with bilateral optic nerve decompression was performed using standard endonasal instruments and rod-lens endoscopes (Karl Storz, 4 mm, 18 cm, Hopkins II; Tuttlingen, Germany) attached to a high-definition camera and monitor.

After the mucosa of the sphenoid was removed and the septations reduced, the ICA and optic canal protuberances as well as the lateral opticocarotid recess (LOCR) and MOCR were identified. Next, using a high-speed drill, the bone of the sella, planum sphenoidale, tuberculum sella, and MOCR, were drilled and removed with aid of Cottle elevators and Kerrison rongeurs. Thereafter, the optic canals were decompressed bilaterally, from the medial aspect of the LOCR to the orbital apex.

Following this, the dura of the sella and planum were opened in cruciate fashion and the optic sheath was incised from medial to lateral on both sides. This exposed the paraclinoid ICA (ie, from the proximal to the distal dural ring; DDR) and intradural ICA (which extends from the distal DDR to the ICA bifurcation),[16] the origin of the ophthalmic artery (just distal to the DDR) and its intracanalicular segment, the optic chiasm, and both, the cisternal and the preforaminal segment of the optic nerve (ie, under the falciform ligament).[14]

The relationships between the proximal course of the ophthalmic artery, the optic nerve, optic canal, MOCR, and ICA were identified and recorded using an Advanced Image and Data Acquisition digital recording system (Karl Storz Endoscopy; Tuttlingen, Germany) for further evaluation.

In all cases, each ICA was labeled similar to a clock face, when viewed from an orthogonal plane through a section of the ICA at the origin of the ophthalmic artery. Accordingly, the ophthalmic artery origin was described as superolateral, superior, or superomedial from the ipsilateral ICA (Figure 1A). A similar method was used to describe the position of the ophthalmic artery origin relative to the optic nerve (Figure 1B).

Finally, using a flexible centimeter grid, measurements of the intracranial length of the ophthalmic artery were obtained on both sides.

In addition, to complement the cadaveric study, the origin of the ophthalmic artery was reviewed in 200 deidentified disease-free 3D reconstructed angiographic studies (86 right and 114 left ICAs) obtained from the Instituto de Neurocirugia Dr Asenjo, Santiago, Chile.

After obtaining informed patient consent following the Human Research Protection Program policies at our university, images from a surgical case were added to further illustrate the surgical relevance of the findings described in the results.

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TABLE 1. Ophthalmic Artery Origin From Internal Carotid Artery

	Right			Left		
Position of Opht. A. origin from the ICA	Cadaveric (%) Sp. (n = 17)	Angio. (%) (n = 86)	Total (%) (n = 103)	Cadaveric (%) Sp. (n = 17)	Angio. (%) (n = 100)	Total (%) (n = 117)
Superior	12 (70.6)	62 (72)	74 (72)	13 (76.5)	69 (69)	82 (70)
Superomedial	3 (17.6)	24 (28)	27 (26)	3 (17.6)	31 (31)	34 (29)
Superolateral	2 (11.8)	0 (0)	2 (2)	1 (5.9)	0 (0)	1 (1)

Angio., angiography; ICA, internal carotid artery; Opht. A., ophthalmic artery; Sp., cadaveric specimen

RESULTS

The ophthalmic artery and MOCR were identified bilaterally in all 17 cadaveric specimens. All studied sphenoid sinuses had a sellar or presellar pneumatization.

Ophthalmic Artery Origin from ICA

In the present study, the ICA was referred using the nomenclature of the ICA road map scheme described by Labib et al.[16] Accordingly, the origin of the ophthalmic artery was described as emerging just distal to the DDR from the intradural segment of the ipsilateral ICA.

In 70.6% (12/17) of specimens, the right ophthalmic artery emerged from the superior, 17.6% (3/17) from the superomedial, while 11.8% (2/17) from the superolateral aspect of the ICA (Table 1; Figure 2A-2G). On the left, 76.5% (13/17), 17.6% (3/17), and 5.9% of the ophthalmic arteries emerged from the superior, superomedial, and superolateral aspects of the ICA, respectively (Figures 1A and 2A-2H)

On angiography, 72% (62/84) of right ophthalmic arteries emerged from the superior aspect, and from the superomedial aspect in 28% (24/84) of the cases. Similarly, 69% (79/114) and 31% (35/114) of left ophthalmic arteries emerged from the superior and superomedial ICA aspects, respectively (Table 1).

Alternative configurations of the origin of the ophthalmic artery, including, but not limited to duplicate vessels, or extradural origin from ICA[11,23,24] were not observed in any of the specimens or imaging samples.

Relationship with the MOCR

In all 34 sides, the origin of the right and left ophthalmic artery was identified just distal to the DDR from the intradural ICA segment at the level of the MOCR (Figures 2A-2H and 3A-3D)

The right and left ophthalmic arteries that originated from the superolateral aspect of the ICA, were found directly posterior to the lateral vertex (the tail)[18] of the MOCR. By contrast, right and left ophthalmic arteries that originated from the ICA's superomedial aspect, were found closely related to the MOCR's medioinferior vertex.[18] On either side, arteries that emerged from the superior aspect, were found midway between the lateral vertex[18] and medial most aspect of the MOCR (3A-D).

Relationship of the Ophthalmic Artery with the Optic Nerve

The optic nerve and optic canal were defined according to Abhinav et al.[14]

Relative to the intracranial segment of the optic nerve, the origin of the ophthalmic artery was found in either of the following presentations: (1) inferolateral, (2) inferomedial, and (3) directly inferior (Figure 1B).

Overall, 47.0%, 26.5%, and 26.5% of the ophthalmic artery origins were found inferolateral, directly inferior, and inferomedial to the intracranial optic nerve segment, respectively (Table 2; Figures 2A-2H and 3B); just proximal to the preforaminal optic nerve segment (ie, the intracranial optic nerve portion roofed by the falciform ligament). No difference was observed between the artery's origin and its position relative to the optic nerve.

Intracranial Length of the Ophthalmic Artery

On both sides, the length of the intracranial segment of the ophthalmic artery (ie, the distance measured from its origin to its exit through the optic canal's proximal opening) ranged from 1.5 to 4.5 mm (mean: 2.83 ± SD 0.71 mm). The artery's mean length was 2.88 ± SD 0.68 mm and 2.78 ± SD 0.77 mm on the right and left side, respectively (Table 3). No difference was found between the vessel's intracranial length and its position of origin from the ICA.

DISCUSSION

The recent expansion of the indications for EEAs requires an understanding of the anatomy of the skull base from an endoscopic perspective.[2-6] Although the microsurgical anatomy of the ophthalmic artery has been established,[10-12] this issue has seldom been discussed from the ventral EEA viewpoint.[13-15]

Injury to the ophthalmic artery results in sight-threatening injury, with a high possibility of irreversible blindness, as it is the major blood supplier to the retina, via the central retinal artery.[13,14,21] Careful examination of preoperative imaging as well intraoperative awareness of the anatomic landmarks is major allies to avoid its accidental injury.[3-5,7,23,25,26]

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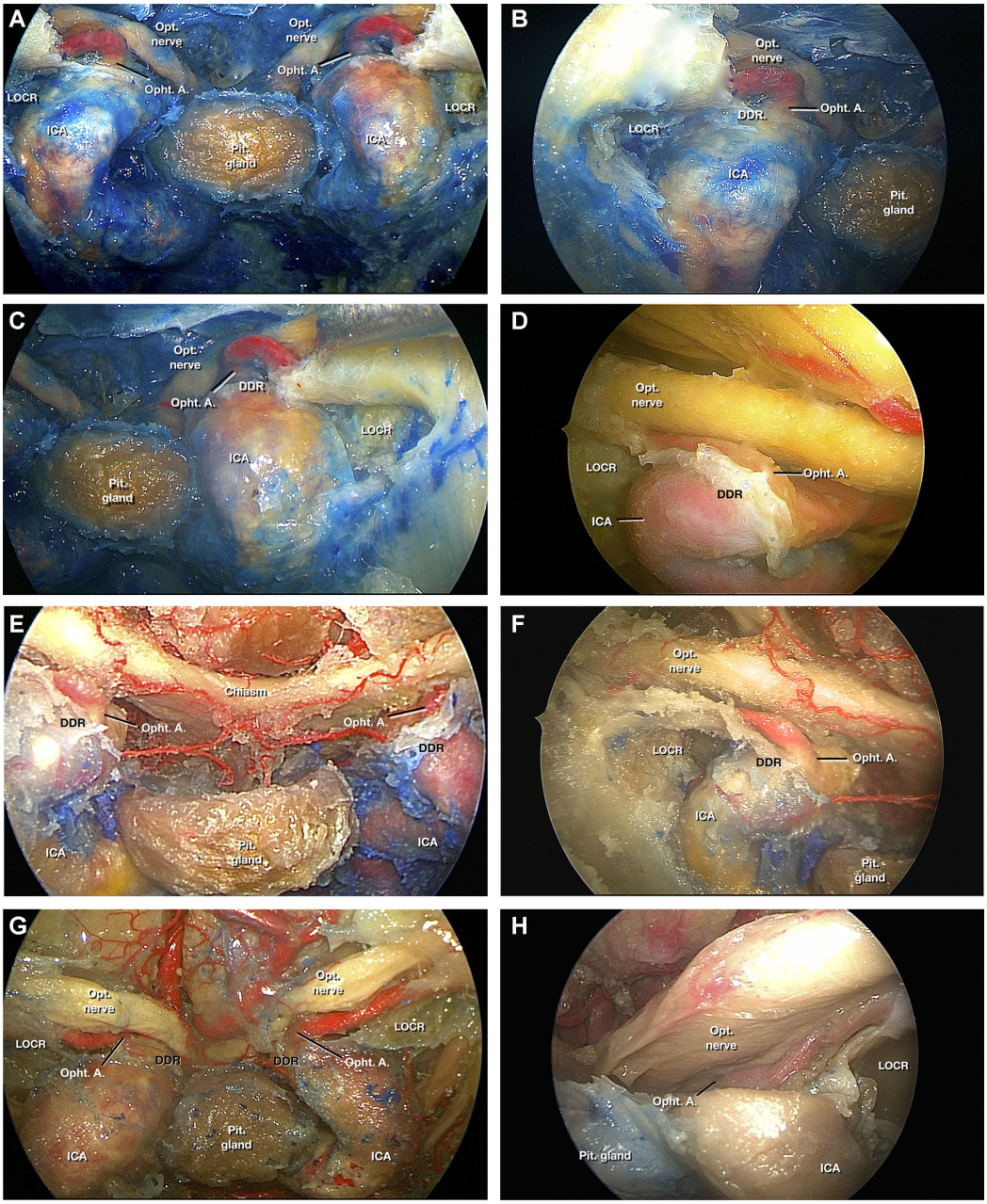


FIGURE 2. *Endonasal endoscopic view of the sellar and suprasellar regions. The relationship of the ophthalmic artery origin with the ICA, optic nerve, and the LOCRis shown. The sella, the medial opticocarotid recess, and the optic canal were drilled.* **A**, *The right and left ophthalmic arteries emerge from the superior aspect of the intradural ICA segment. On both sides, the ophthalmic artery origin is positioned inferomedial to the optic nerve.* **B**, *The close-up view of the right and* **C**, *left ophthalmic artery origin.* **D**, *The medial view of the right ophthalmic artery. Here, the right ophthalmic artery emerges from the superomedial position of the intradural ICA segment and is positioned inferomedial to the optic nerve.* **E**, *The right and left ophthalmic arteries are seen emerging from the superomedial and superior aspects of the right and left intradural ICA segments respectively. The right ophthalmic artery origin is positioned inferomedial, while on the left, it is directly inferior to the optic nerve.* **F**, *The medial view of right ophthalmic artery origin.* **G**, *The right and left ophthalmic arteries are seen emerging from the superolateral and superomedial aspects of the ICA and are positioned inferolateral and inferomedial to the optic nerve, respectively.* **H**, *left ophthalmic artery origin from the inferolateral aspect of the intradural ICA segment. Chiasm, optic chiasm; DDR, distal dural ring; ICA, internal carotid artery; LOCR, lateral opticocarotid recess; Opht. A., ophthalmic artery; Opt. nerve, optic nerve; Pit. gland, pituitary gland.*

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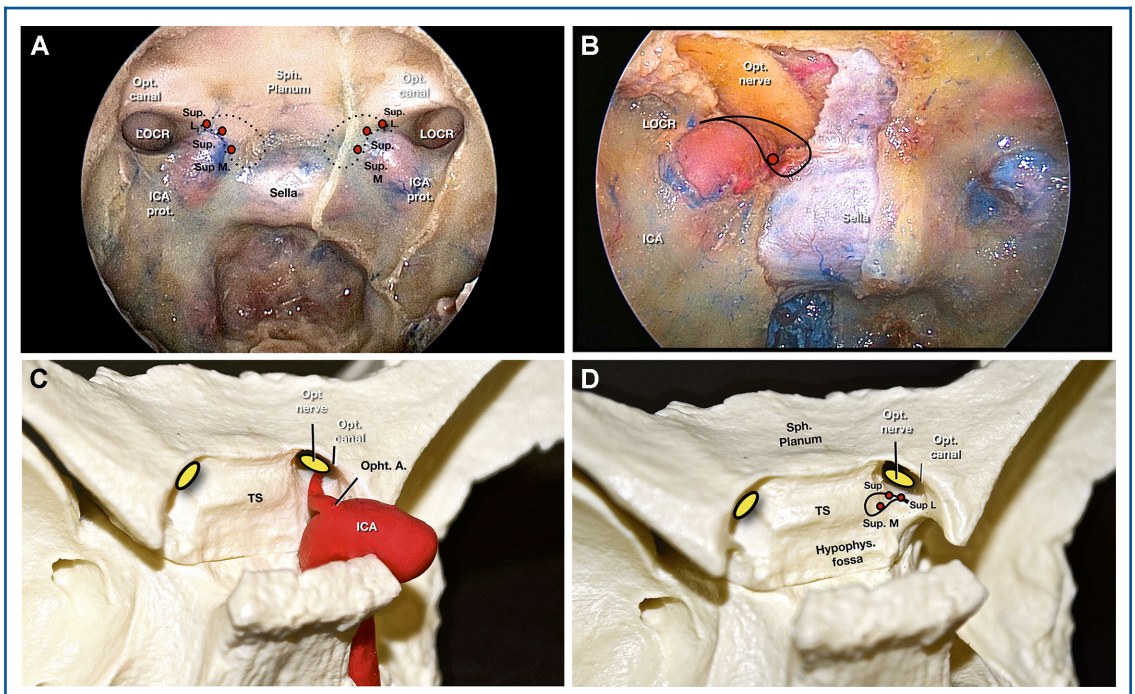


FIGURE 3. *Endonasal endoscopic view of sphenoidal landmarks.* **A**, *The position of the superolateral, superior, and superomedial ophthalmic artery origins (red circles) relative to the medial opticocarotid recess (MOCR) are shown.* **B**, *The right MOCR was drilled, and the underlying dura was opened, exposing the ophthalmic artery origin (highlighted by the red circle) from the superomedial aspect of the intradural ICA, left superolateral dorsal view of the sellar and parasellar areas* **C-D**. **C**, *The ICA and ophthalmic artery are represented with molding material, and the ophthalmic artery emerges from the superomedial aspect of the ICA.* **D**, *Shows the position of the superolateral, superior, and superomedial ophthalmic artery origins (red circles) relative to the MOCR (black tear-drop-shaped area). On either side, ophthalmic arteries emerging from the lateral aspect of the ICA are found at the level of the lateral vertex of the MOCR. On the other hand, ophthalmic arteries that emerge from the medial aspect of the ICA are present at the level of the medio-inferior vertex of the MOCR. Arteries arising from the superior aspect of the ICA, were found midway at the level between the lateral vertex and medial aspect of the recess. Hypophys. fossa, hypophyseal fossa; ICA, internal carotid artery; ICA prot., internal carotid artery protuberance; LOCR, lateral opticocarotid recess; Opt. canal, optic canal; Opt. nerve, optic nerve; Sup., superior ophthalmic artery origin; Sph. planum, sphenoid planum; Sup. L., superolateral ophthalmic artery origin; Sup. M., superomedial ophthalmic artery origin; TS, tuberculum sella.*

TABLE 2. Position of Ophthalmic Artery Origin Relative to the Intracranial Optic Nerve Segment

Opht. A. origin relative to the Opt. nerve	Right (n = 17)	Left (n = 17)	Total (%) (n = 34)
Inferolateral	8	8	16 (47)
Inferior	4	5	9 (26.5)
Inferomedial	5	4	9 (26.5)

Opht. A., ophthalmic artery; Opt. nerve, optic nerve

TABLE 3. Intracranial Length of Ophthalmic Artery

	Right (n = 17)	Left (n = 17)	Total (n = 34)
Mean length (mm) ± SD	2.88 ± 0.69	2.78 ± 0.78	2.90 ± 0.74

SD, standard deviation

Herein, we further define the anatomy of the origin of the ophthalmic artery, as seen endoscopically through the endonasal corridor. In addition, to complement the cadaveric study, the origins of 200 ophthalmic arteries were assessed with angiographic imaging. Its acute injury management and rate of complications go beyond the scope of this paper and has been reviewed elsewhere.[27]

The Origin of the Ophthalmic Artery

From a microsurgical standpoint, the origin of the ophthalmic artery has been described previously as arising above the cavernous sinus, from the superomedial aspect of the supraclinoid ICA, distal to the DDR and behind the optic canal.[10] However, from the endonasal perspective, its anatomic appearance, and that of the surrounding structures is different to what can be appreciated transcranially.[13,14,15] Moreover, with the recent description of the ICA road map[16]—a classification system

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specific for ventral approaches—an endoscopic assessment of the ophthalmic artery using the new nomenclature is warranted.

This study described the origin of the ophthalmic artery as emerging just distal to the DDR from the superolateral, superior, or superomedial aspect of the intradural segment of the ICA (Figures 1A and 2A-2H). In the majority of the cadaveric specimens, the ophthalmic artery emerged from the superior aspect of the right and left intradural ICAs (70.6% and 76.5%, respectively). On the right side, the remainder ophthalmic arteries emerged from the superomedial and superolateral aspects (17.6% and 11.8%, respectively), while on the left side, the remainder arteries emerged from the ICA's superomedial (17.6%) and superolateral (5.9%) aspects. The cadaveric findings were comparable to those observed on angiography (Table 1).

The MOCR as a Landmark for the Origin of the Ophthalmic Artery

Under endoscopic view, the MOCR is described as teardrop-shaped indentation at the junction of the tuberculum sellae, paraclinoid ICA protuberance, optic canal, and planum sphenoidale.[3,4,16,17,20] Comparable to the "keyhole"[4,20] of pterional craniotomy, as detailed by Labib et al, the role of the MOCR is two-fold[18]:

(1) To serve as an entry point, providing access the structures comprising its borders including the paraclinoid ICA and the optic canal.[3-5,13,14,18,22,26,28-30]
(2) To act as an anatomic boundary to the lateral expansion of sellar and parasellar approaches.[16,18]

A recent study reported the relationship between the MOCR and the preforaminal optic nerve segment.[14] However, to our knowledge, this is the first study to describe the MOCR as a landmark for the ophthalmic artery.

In the present study, in all 34 sides, the ophthalmic artery arose intradurally, just distal to the DDR, at the level of the MOCR (Figures 2A-2H and 3B). Right and left ophthalmic arteries that emerged from the superolateral aspect of the ICA, were found at the level of the lateral vertex of the MOCR[18] (Figures 2G-2H, 3A and 3D). On the other hand, right and left ophthalmic arteries that emerged from the ICA's superomedial aspect, were found at the level of the medio-inferior vertex of the MOCR[18] (Figures 2D-2G and 3A-3D).

Arteries arising from the superior aspect of the ICA, were found midway at the level between the lateral vertex and medial most aspect of the recess. (Figures 2A-2C, 3A and 3D). Interestingly, its origin was never found beyond the confines of the MOCR (Figures 2A-2H).

Relationship Between the Origin of the Ophthalmic Artery and the Intracranial Optic Nerve Segment

Overall, the origin of the ophthalmic artery was present inferolateral, directly inferior, and inferolateral to the intracranial optic nerve in 47%, 26.5%, and 26.5% of the cases, respectively (Figures 1B, 2A-2H, and 3B; Table 2). This differs slightly to the study by Abhinav et al (10 cadaveric specimens; 20 sides),[14] where, overall, the ophthalmic artery arose lateral, inferolateral, and inferomedial to the intracranial optic nerve in 5%, 15%, and 80% of the cases, respectively, and to the findings by Locatelli et al (6 cadaveric specimens; 12 sides),[15] who reported that 20%, 30%, and 50% of the arteries arose inferolateral, inferomedial, and inferior to the nerve, respectively.

In cases where the ophthalmic artery arises inferolateral to the optic nerve, the vessel is considered to be "protected" when approached with an EEA line-of-sight, as it is not immediately found upon the opening of the dura of the MOCR.[13,29,32,33] On the other hand, for the rest of the cases where the ophthalmic artery is positioned inferomedial (Figures 4A-4D) or directly inferior to the optic nerve, careless manipulation of the MOCR dura may result in dire visual consequences from inadvertent injury.[12,28,31,32] Given the relative variability of the artery's origin relative to the optic nerve, a thoughtful planning process, anatomic awareness, and the efficient use of intraoperative image guidance is essential.

Recently, Abhinav et al,[14] described a method opening the dura for avoiding injury to the ophthalmic artery during endonasal resection of tumors extending into the preforaminal optic nerve and true optic canal invasion. Their method of opening the dura and cutting ligament and DDR is highly efficient by enabling early visualization the ophthalmic artery and optic nerve before opening the OC.[14] Like them, we would like to emphasize that extreme care should be exercised when making the lateral cut on the DDR, particularly given the incidence of ophthalmic arteries arising from the ICA's superior and superomedial aspects.[14]

In addition, to avoid injuring the ophthalmic artery and optic nerve, drilling of the MOCR and the proximal portion of the canal, may be safer if carried out along the recesses' and optic canal's superomedial edge. Once eggshell thinned, the bone should be outfractured in a craniocaudal direction away from the underlying dural and optic sheath; exercising particular care during the removal of the inferior most portions.[14,19,33] In general, blind dissection with Kerrison rongeurs should be avoided during opening of the canal to minimize the risk of injuring the vessel. Furthermore, when indicated, the opening of the optic sheath, should be carried out lateral to the MOCR along the upper edge of the canal.

Intracranial Length of the Ophthalmic Artery

The findings of the mean length of the intracranial segment of the ophthalmic artery are presented in Table 3. These findings are comparable to those of previous studies.[13,14]

Limitations

While this study provides a detailed description of the origin of the ophthalmic artery from the EEA perspective, it is limited by several factors. In particular, the use of cadaveric and imaging

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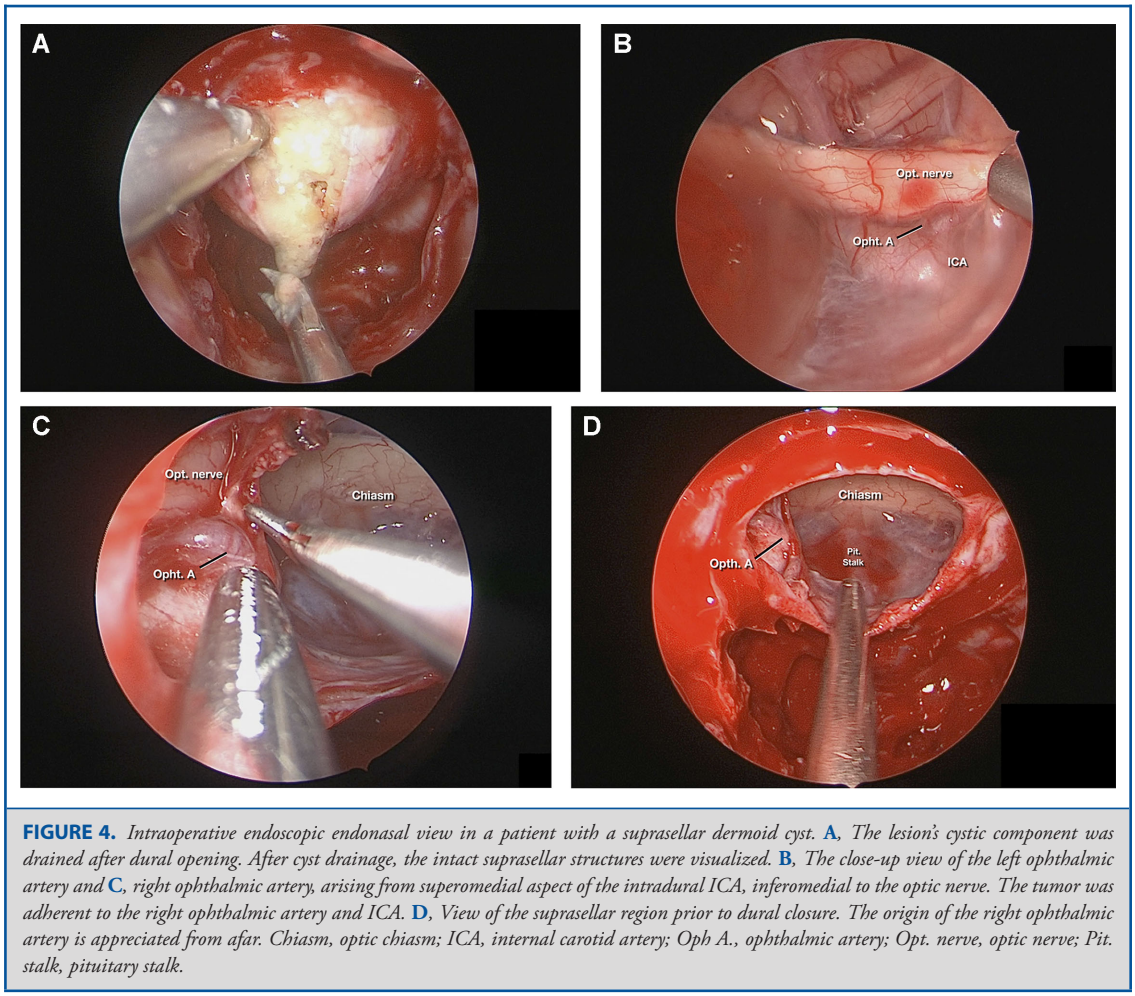


FIGURE 4. *Intraoperative endoscopic endonasal view in a patient with a suprasellar dermoid cyst.* **A**, *The lesion's cystic component was drained after dural opening. After cyst drainage, the intact suprasellar structures were visualized.* **B**, *The close-up view of the left ophthalmic artery and* **C**, *right ophthalmic artery, arising from superomedial aspect of the intradural ICA, inferomedial to the optic nerve. The tumor was adherent to the right ophthalmic artery and ICA.* **D**, *View of the suprasellar region prior to dural closure. The origin of the right ophthalmic artery is appreciated from afar. Chiasm, optic chiasm; ICA, internal carotid artery; Oph A., ophthalmic artery; Opt. nerve, optic nerve; Pit. stalk, pituitary stalk.*

samples free of skull base disease must be recognized. This, however, only serves to further emphasize the importance of a meticulous planning process and comprehensive familiarity with the skull base anatomy knowledge as well as the use of intraoperative image-guidance with CT angiography and devices such as Doppler ultrasound for best outcomes.[13,14,27]

CONCLUSION

Preoperative awareness of the origin of the ophthalmic artery, combined with a detailed intraoperative understanding of its relationship with the ICA, MOCR, and optic nerve, is paramount for predicting its location, and thus, minimize the risk of injuring it inadvertently during EEAs to the supra- and parasellar regions. Further anatomic studies from a ventral perspective are warranted to improve the safety of endoscopic endonasal procedures.

Disclosures

Dr Carrau is a consultant for Medtronic and Stryker Corporations. Dr Prevedello is a consultant for Medtronic, Codman, and Stryker Corporations, has received honoraria from Leica Microsystems, and has a royalty agreement with KLS-Martin Inc. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Chandra RK, Conley DB, Kern RC. Evolution of the endoscope and endoscopic sinus surgery. *Otolaryngol Clin North Am*. 2009;42(5):747-752, vii.
2. Stammberger H, Anderhuber W, Walch C, Papaefthymiou G. Possibilities and limitations of endoscopic management of nasal and paranasal sinus malignancies. *Acta Otorhinolaryngol Belg*. 1999;53(3):199-205.
3. Kassam AB, Gardner P, Snyderman C, Mintz A, Carrau R. Expanded endonasal approach: fully endoscopic, completely transnasal approach to the middle third of the clivus, petrous bone, middle cranial fossa, and infratemporal fossa. *Neurosurg Focus*. 2005;19(1):1-10.
4. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. *Neurosurg Focus*. 2005;19(1):E3.
5. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. *Neurosurg Focus*. 2005;19(1):E4.
6. Cappabianca P, Cavallo LM, Esposito F, De divitiis O, Messina A, De divitiis E. Extended endoscopic endonasal approach to the midline skull base: the evolving role of transsphenoidal surgery. *Adv Tech Stand Neurosurg*. 2008;33:151-99.

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7. Snyderman C, Kassam A, Carrau R, Mintz A, Gardner P, Prevedello DM. Acquisition of surgical skills for endonasal skull base surgery: a training program. *Laryngoscope*. 2007;117(4):699-705.
8. Kassam AB, Prevedello DM, Carrau RL, et al. Endoscopic endonasal skull base surgery: analysis of complications in the authors' initial 800 patients. *J Neurosurg*. 2011;114(6):1544-1568.
9. Kshettry VR, Do H, Elshazly K, et al. The learning curve in endoscopic endonasal resection of craniopharyngiomas. *Neurosurg Focus*. 2016;41(6):E9.
10. Perrini P, Cardia A, Fraser K, Lanzino G. A microsurgical study of the anatomy and course of the ophthalmic artery and its possibly dangerous anastomoses. *J Neurosurg*. 2007;106(1):142-150.
11. Rhoton AL. The orbit. *Neurosurgery*. 2002;51(4 Suppl):S303-S334.
12. Erdogmus S, Govsa F. Anatomic features of the intracranial and intracanalicular portions of ophthalmic artery: for the surgical procedures. *Neurosurg Rev*. 2006;29(3):213-218.
13. Zoli M, Manzoli L, Bonfatti R, et al. Endoscopic endonasal anatomy of the ophthalmic artery in the optic canal. *Acta Neurochir*. 2016;158(7):1343-1350.
14. Abhinav K, Acosta Y, Wang WH, et al. Endoscopic endonasal approach to the optic canal. *Neurosurgery*. 2015;11(Suppl 3):431-446.
15. Locatelli M, Caroli M, Pluderi M, et al. Endoscopic transsphenoidal optic nerve decompression: an anatomical study. *Surg Radiol Anat*. 2011;33(3):257-262.
16. Labib MA, Prevedello DM, Carrau R, et al. A road map to the internal carotid artery in expanded endoscopic endonasal approaches to the ventral cranial base. *Neurosurgery*. 2014;10(Suppl 3):448-471.
17. Kassam A, Labib MA, Prevedello DM, Carrau R. In reply: An endoscopic roadmap of the internal carotid artery. *Neurosurgery*. 2015;77(1):E154-E155.
18. Labib MA, Prevedello DM, Fernandez-miranda JC, et al. The medial opticocarotid recess: an anatomic study of an endoscopic "key landmark" for the ventral cranial base. *Neurosurgery*. 2013;72(1 Suppl Operative):66-76.
19. Kulwin C, Schwartz TH, Cohen-gadol AA. Endoscopic extended transsphenoidal resection of tuberculum sellae meningiomas: nuances of neurosurgical technique. *Neurosurg Focus*. 2013;35(6):E6.
20. Kassam AB, Gardner PA, Snyderman CH, Carrau RL, Mintz AH, Prevedello DM. Expanded endonasal approach, a fully endoscopic transnasal approach for the resection of midline suprasellar craniopharyngiomas: a new classification based on the infundibulum. *J Neurosurg*. 2008;108(4):715-728.
21. Ozcan T, Yilmazlar S, Aker S, Korfali E. Surgical limits in transnasal approach to opticocarotid region and planum sphenoidale: an anatomic cadaveric study. *World Neurosurg*. 2010;73(4):326-333.
22. Liu JK, Christiano LD, Patel SK, Tubbs RS, Eloy JA. Surgical nuances for removal of tuberculum sellae meningiomas with optic canal involvement using the endoscopic endonasal extended transsphenoidal transplanum transtuberculum approach. *Neurosurg Focus*. 2011;30(5):E2.
23. Belotti F, Ferrari M, Doglietto F, et al. Ophthalmic artery originating from the anterior cerebral artery: anatomo-radiological study, histological analysis, and literature review. *Neurosurg Rev*. 2016;39(3):483-493.
24. Louw L. Different ophthalmic artery origins: Embryology and clinical significance. *Clin Anat*. 2015;28(5):576-583.
25. Dolci RL, Carrau RL, Buohliqah L, et al. Endoscopic endonasal anatomical study of the cavernous sinus segment of the ophthalmic nerve. *Laryngoscope*. 2015;125(6):1284-1290.
26. Barges-coll J, Fernandez-miranda JC, Prevedello DM, et al. Avoiding injury to the abducens nerve during expanded endonasal endoscopic surgery. *Neurosurgery*. 2010;67(1):144-154.
27. Romero ADCBLal gangadharan J, Bander ED, Gobin YP, Anand VK, Schwartz TH. Managing arterial injury in endoscopic skull base surgery: Case series and review of the literature. *Oper Neurosurg (Hagerstown)*. 2017;13(1):138-149.
28. Kikuchi R, Toda M, Wakahara S, Fujiwara H, Jinzaki M, Yoshida K. Analysis of the medial opticocarotid recess in patients with pituitary macroadenoma using three-dimensional images. *World Neurosurg*. 2016;93:139-143.
29. Yilmazlar S, Saraydaroglu O, Korfali E. Anatomical aspects in the transsphenoidal-transethmoidal approach to the optic canal: an anatomic-cadaveric study. *J Craniomaxillofac Surg*. 2012;40(7):e198-e205.
30. Sharma A, Rieth GE, Tanenbaum JE, et al. A morphometric survey of the parasellar region in more than 2700 skulls: emphasis on the middle clinoid process variants and implications in endoscopic and microsurgical approaches. *J Neurosurg*. 2018;129(1)60-70.
31. Lai LT, Morgan MK, Snidvongs K, Chin DC, Sacks R, Harvey RJ. Endoscopic endonasal transplanum approach to the paraclinoid internal carotid artery. *J Neurol Surg B*. 2013;74(06):386-392.
32. Luxenberger W, Stammberger H, Jebeles JA, Walch C. Endoscopic optic nerve decompression: the Graz experience. *Laryngoscope*. 1998;108(6):873-882.
33. Li J, Wang J, Jing X, Zhang W, Zhang X, Qiu Y. Transsphenoidal optic nerve decompression. *J Craniofac Surg*. 2008;19(6):1670-1674.

COMMENT

The authors provide a detailed anatomic description of the position of the ophthalmic artery and its relative position to the optic nerve and MOCR in 17 cadaveric specimens bilaterally. The radiographic origin of the ophthalmic artery relative to the ICA was also studied in 200 "normal" angiograms. The origin and position of the ophthalmic artery is highly relevant as more expanded endoscopic endonasal approaches are being performed. The risk to the ophthalmic artery needs to be assessed preoperatively, planned for, and protected intraoperatively. The authors of this study evaluated the position of the ophthalmic artery relative to the aforementioned anatomy in an effort to assist surgical teams in predicting the position of the ophthalmic artery and thereby minimize the surgical risk of injury. While this study is predictive and does not apply to the individual patient, it serves as guide. It further highlights the importance of mindfulness and technique in more safely opening the dura and addressing paraophthalmic pathology. The anatomic knowledge can be applied to transcranial approaches to the paraophthlamic region as well. Next steps could be a multicentered study whereby surgical teams report their intraoperative observation of the relative anatomy of the ophthalmic artery relative to the ICA, MOCR, and optic nerve.

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