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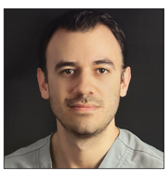
Original Article

Anatomy of the medial wall of the orbit undergoing an endoscopic endonasal approach: An inferomedial and superomedial approach

Marco Antonio Garfias-Rodriguez[1], Victor Ramzes Chavez-Herrera[2], Juan Pablo Ichazo-Castellano[1], Erick Zepeda[2], David Gallardo-Ceja[3], Agustín Dorantes-Argandar[4]

[1]Department of Neurosurgery, Center for Skull Base Neurosurgery and Minimally Invasive Neurosurgery, Hospital Angeles Pedregal, Center for Surgical Specialties, Surgical Neuroanatomy Laboratory, Mexican School of Medicine of Universidad La Salle, [2]Department of Neurosurgery, Centro Medico Nacional Siglo XXI, IMSS, [3]Department of Neurosurgery, Hospital Angeles del Pedregal, [4]Center for Cranial Base Surgery, Hospital Angeles Pedregal, Mexico City, Mexico.

E-mail: Marco Antonio Garfias-Rodriguez - marco_garfias16@hotmail.com; *Victor Ramzes Chavez-Herrera - ramzes.chavez@gmail.com; Juan Pablo Ichazo-Castellano - pablo_icha@hotmail.com; Erick Zepeda - erickzf@hotmail.com; David Gallardo-Ceja - gallardocd@gmail.com; Agustín Dorantes-Argandar - agustin.dorantes@gmail.com



***Corresponding author:**
Victor Ramzes Chavez-Herrera,
Department of Neurosurgery,
Centro Medico Nacional
Siglo XXI, IMSS, Mexico City,
Mexico.

ramzes.chavez@gmail.com

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ABSTRACT

Background: Endoscopic endonasal corridor is valuable for accessing and treating midline skull base pathologies. In the present work, we will discuss the anatomy of the medial wall of the orbit from an endonasal endoscopic perspective.

Methods: Six human cadaveric specimens underwent endonasal endoscopic dissection at the Surgical Neuroanatomy Laboratory of the Mexican Faculty of Medicine of La Salle University. We used a 0°, 4 mm diameter, and 18 cm length rigid endoscope using a 4K high-definition neuro-endoscopic visualization system, specialized surgical instruments for endonasal endoscopic surgery, and a high-speed drilling system.

Results: In the endonasal endoscopic to the medial wall of the orbit, we describe two approaches: the superomedial approach (SMA) and the inferomedial approach (IMA). The SMA is located between the lower border of the superior oblique muscle and the superior border of the medial rectus muscle (MRM), and the IMA is located between the inferior border of the MRM and the superior border of the inferior rectus muscle. The topographic anatomy of the contents of each approach is described.

Conclusion: The endoscopic endonasal corridor safely reaches the medial half of the orbit through the inferomedial and SMAs.

Keywords: Anatomy, Endonasal endoscopic, Medial wall of the orbit, Transpapyraceous

INTRODUCTION

The anatomy of the orbit is complex, with a variety of delicate neurovascular, muscular, and connective tissue structures. Conventionally, the corridor will depend on the specific area of the orbit being affected; the most used include transcranial transorbital and its variations, such as transconjunctival, transtarsal, lateral orbitotomy, pterional craniotomy, orbitocranial, orbitozygomatic, frontal basal, and their combinations. In addition, endonasal endoscopic approaches are now the leading practice when treating midline skull base pathologies, including through the medial wall of the orbit (transpapyraceous). This is true due to their less invasive nature, which accomplishes better outcomes.[1,10]

The initial use of the endoscope to the medial wall of the orbit was to address optic nerve (ON) decompression resulting from Graves' orbitopathy, as well as fractures of the floor and medial wall of the orbit due to traumatic causes. Since its introduction, the endoscope has become an indispensable instrument for endonasal surgery and has demonstrated that it is a suitable corridor for treating tumor pathology.[4,5]

To perform a safe and effective endonasal endoscopic transpapyraceous approach (TPA), it is imperative to master anatomy from an endoscopic perspective. This will prevent injuring neurovascular structures, especially the proper location of the ON, the ophthalmic artery (OA), and its ethmoidal branches, to avoid vascular injury.[7]

In the present work, we describe the overview of common orbital tumors, the anatomy of the orbit from an inferomedial and superomedial perspective employing an endonasal endoscopic TPA, as well as the identification of key anatomical limits and content. This could be beneficial when treating conditions found in these complicated areas.[2,20]

MATERIALS AND METHODS

Six cadaveric human biological specimens were preserved in a 70% alcohol solution and refrigerated. A Mayfield head holder was used to keep the head in a neutral position. The use of cadaveric heads adhered to our institution's ethical standards and regulations. No Institutional Review Board approval was required for this cadaveric study. The study was performed at the Surgical Neuroanatomy Laboratory of the Mexican Faculty of Medicine of the University of La Salle. Endonasal endoscopic dissections were performed using a 0°, 4 mm diameter, and 18 cm length rigid endoscope (Karl Storz and Co, Tuttlingen, Germany) attached to a 4K high-definition neuro-endoscopic visualization system. Furthermore, specialized surgical instruments for endonasal endoscopic surgery and a high-speed surgical drill with endoscopic compatibility (Medtronic MidasRex electric system; Medtronic USA Inc., Jacksonville, Florida, United States). To better understand the anatomy, we performed a comprehensive bilateral sphenoidectomy, posterior and anterior ethmoidectomies, and posterior septectomy. Photographs and videos were taken from the visualization system. The digital application platform "Procreate" was used in all illustrations. All patients underwent a binostril endonasal endoscopic corridor, and transpapyraceous SMA and IMA exclusive of any orbital pathology, and no exclusion criteria were applied.

RESULTS

Endonasal endoscopic TPA

The introduction of the endoscope using binostral access to the nose was implemented, and the inferior turbinate was identified with subsequent medialization and lateralization until a subtle fracture of the turbinate was felt. Sequentially, the middle retroturbinal anatomical structures were recognized, and bilateral middle turbinectomy was performed; we identified the uncinate process, superior semilunar hiatus, ethmoidal bulla, inferior semilunar hiatus, and retrobullar recess. The sphenopalatine artery emerging from the foramen of the same name was identified. Anterior ethmoidectomy was performed with cutting instruments. The posterior ethmoidal cells were recognized, and mucosal and bone resection was performed progressively; in most specimens, the presence of Onodi's cells was recognized. Subsequently, a septectomy was performed through the posterior portion. The sphenoid rostrum was visualized, and a wide anterior sphenoidectomy was performed (from the vidian-to-vidian canal in a coronal plane and from planum to vomer in a sagittal plane).[3,12,39]

Finally, laterally, the presence of the medial wall of the orbit (lamina papyraceae) was recognized bilaterally, proceeding to perform the transpapyraceous orbitotomy using a high-speed drill to visualize the intraconal structures from a superior, lower, and medial perspective, formed by the lamina papyraceae from the orbital floor to the junction of the lamina cribrosa, Fovea ethmoidalis and pars orbitaria of the frontal bone, and anterior opening from the lacrimal bone to the optic foramen. The periorbit was opened using endoscopic microsurgery techniques without transgressing the orbital fat with the conal contents. Subsequently, the muscle limits are identified, and the appropriate window to treat the orbital pathology is chosen.[23,40]

After performing the TPA, we defined the presence of two accesses from an inferomedial and superomedial perspective arranged in a triangular shape. In both, the apex is the annular tendon (AT), the insertion site of the four rectus muscles, and the base is the posterior portion of the eye. The inferomedial approach (IMA) is delimited superiorly by the medial rectus muscle (MRM) and inferiorly by the inferior rectus muscle (IRM), as shown in Figures 1-3. In addition, the superomedial approach (SMA) is delimitated superiorly by the superior oblique muscle (SOM) and inferiorly by the MRM, as shown in Figures 4 and 5.

SMA and inferomedial approach limits and contents

SMA

Limits
- Superiorly: SOM
- Inferiorly: MRM
- Apex: AT
- Base: Eye.

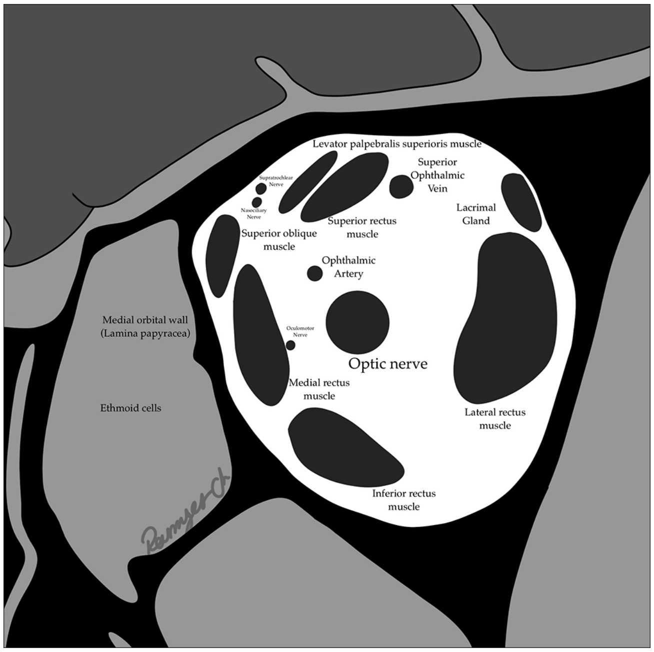

Figure 1: Digital illustration of the anatomy of the orbit.

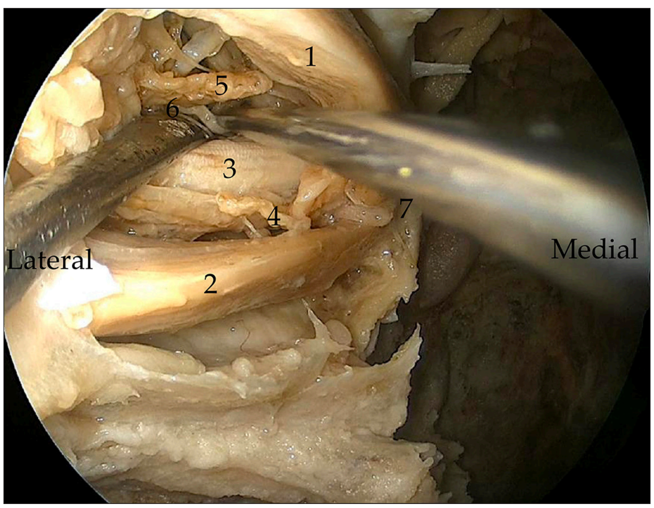

Figure 2: Inferomedial window (1) medial rectus muscle; (2) inferior rectus muscle; (3) optic nerve; (4) inferior branch of III cranial nerve; (5) ophthalmic artery; (6) ciliary branches; and (7) annulus tendon.

Content

- Upper branch of the III cranial nerve (CN)
- Anterior and posterior ethmoidal branches
- Superior rectus muscle (SRM).

Inferomedial approach (IMA)

Limits

- Superiorly: MRM
- Inferiorly: IRM

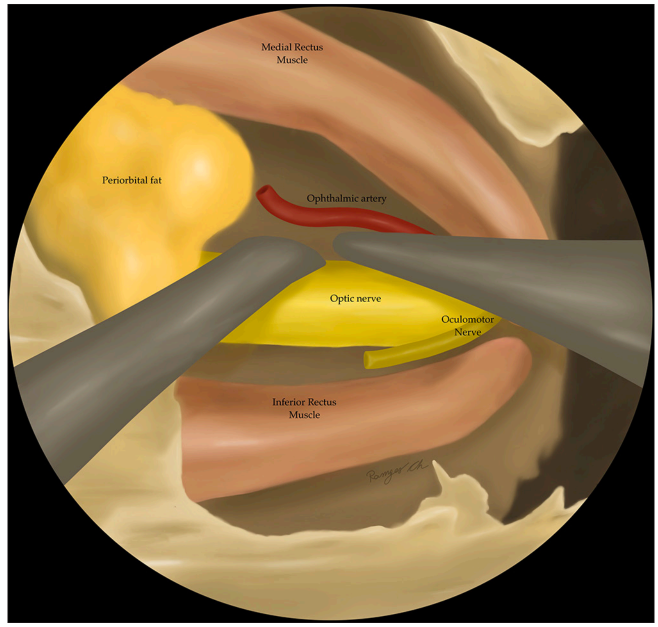

Figure 3: Digital illustration of the inferomedial approach.

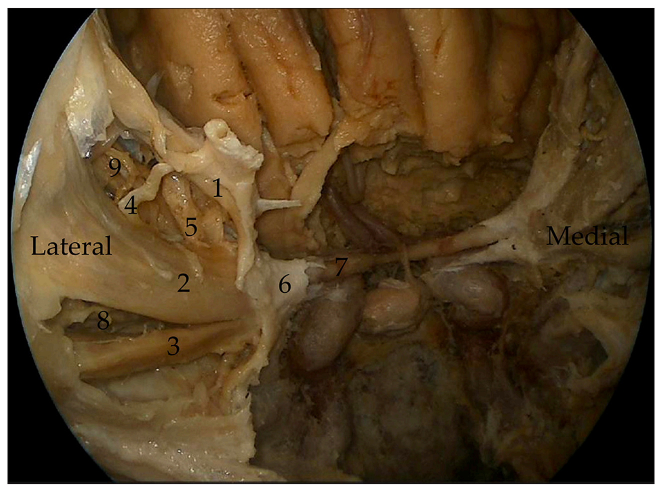

Figure 4: Superomedial approach (1) superior oblique muscle; (2) medial rectus muscle; (3) inferior rectus muscle; (4) posterior ethmoidal artery; (5) superior branch of III cranial nerve; (6) annulus tendon; (7) intracranial optic nerve, (8) inferomedial approach; and (9) superior rectus muscle.

- Apex: AT
- Base: Eye

Content

- ON (intraorbital and intraocular portion)
- III CN and division into its upper and lower branches
- OA
- Nasociliary nerve
- Short and long ciliary branches

Within the SMA, the superior branch of the III CN emerges in the inferomedial window, passes superior and lateral to the

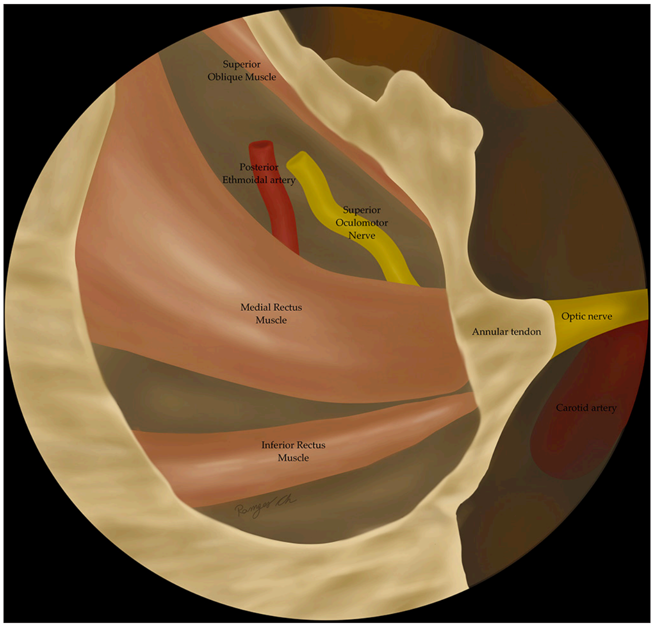

Figure 5: Digital illustration of the supermedial approach.

ON, and then moves medial to lateral toward the SRM and levator palpebrae superioris. Furthermore, the ethmoidal branches, which emerge from the OA, are generally superolateral to the ON and are directed, from lateral to medial, toward their foramina in the frontoethmoidal suture, which has been unroofed in this specimen [Figures 1-3] and heads toward their intracranial exit at the lateral border of the vertical plate of the lamina cribosa.[20]

Within the IMA, the third and fourth portions of the ON (from proximal to distal), which are located above the IRM and lower than the MRM, follow a discrete trajectory from superior to inferior toward the eye [Figures 4 and 5]. Furthermore, in its proximity to the AT, the ON sheath merges upward within the periorbit.[26,34]

The presence of the OA is generally superior and lateral to the ON and parallel to the trajectory of the ON. Likewise, the nasociliary nerve, a branch of the maxillary nerve, follows a trajectory similar to the OA and is superior and lateral to the ON. In addition, it is worth noting that the ciliary branches of the OA are positioned below the optic nerve and run parallel to the IRM.[21]

DISCUSSION

Orbital tumors

Less than 1% of head and neck tumors are orbital tumors. The orbit's topography and its contents, which include a wide variety of neurovascular, mesenchymal, and lymphoid structures, make it a common site for primary tumors, as well as metastases or secondary tumors.[16]

The most common orbital tumors are hemangioma, non-Hodgkin's lymphoma, inflammatory tumors, meningioma, and optic nerve glioma. However, inflammatory lesions such as Graves' disease and orbital pseudotumor represent up to 25% of all orbital lesions.[35]

The most common secondary tumors are mucoceles, squamous cell carcinomas, meningiomas, vascular malformations, and basal cell carcinoma, among others. The most frequent metastases affecting both the eye and its orbital contents originate from lung and breast primary tumors.[14]

Shields and Shields report that the incidence of orbital tumors was as follows: cystic tumors (30%), inflammatory tumors (13%), tear duct lesions (13%), secondary tumors (11%), lymphoid tumors (10%), and vascular tumors (6%).[38]

Within the pediatric population, most orbital tumors are considered benign, considering that 1 in 3 tumors will have malignant behavior. The most common benign tumors are hemangioma, lymphangioma, dermoid cysts, optic nerve glioma, and inflammatory tumors. The most frequent malignant tumors are rhabdomyosarcoma, Ewing's sarcoma, metastatic neuroblastoma, intraorbital extension of the most frequent ocular tumor, and retinoblastoma.[18,24]

We could consider classifying the main orbital tumors according to age group into infantile (newborns to adolescents) and adult tumors and according to their histological lineage, whether they have a neurogenic, lymphoproliferative, vascular, mesenchymal, or secondary origin, as shown in Table 1.[16]

Because the surrounding structures of the orbit are osseous, when there is an occupying lesion in it, regardless of the intraorbital quadrant in which it is located, the force vectors are directed toward the weakest region, in this case, the eye, forcing its extraconal extrusion. That is why the most frequent symptom in patients with orbital tumors is proptosis of lesser to greater degree, followed by ophthalmoparesis/ophthalmoplegia, alteration of visual acuity, painful ophthalmopathy, etc.[27,30]

Anatomy of the orbit

The orbit is a complex bone cavity that combines various cranial and facial bones. Its content is a muscular, ligament, and neurovascular complex whose primary function is to protect the eye and retina from trauma, both external and luminous. In addition, it serves as a modulator of the light stimulus due to its eyelid skin protection. The muscular structures innervated by the oculomotor nerves carry out the mobility of the eye with ligament, adipose, and connective tissue limitations.[25,37]

The orbit communicates intracranially to the anterior and middle floor and the facial region through the infratemporal and pterygopalatine fossa (from lateral to medial).[11,17]

Table 1: Classification of orbital tumors ON.

Orbital tumor	Children	Adults
Neurogenic	Retinoblastoma/ON Glioma	ON Meningioma
Lymphoproliferative	Lymphangioma	Non-Hodgkin lymphoma
Vascular	Hemangioma	Cavernous angioma
Mesenchymatous	Dermoid cyst/Rhabdomyosarcoma	Dermoid cyst/Rhabdomyosarcoma
Others	Mucocele/Inflammatory pseudotumor	Graves' disease/Metastasis

ON: Optic nerve

CNs and intraconal irrigation reach the orbit through different osseous apertures (optic foramen, superior orbital fissure, inferior orbital fissure, anterior and posterior ethmoid foramina, supraorbital foramen, supraorbital fissure, and infraorbital foramen).[6,28]

Bone relationships

The orbit walls are made up of seven bones (from lateral to medial): the zygomatic, maxillary, frontal, sphenoidal, ethmoidal, palatal, and lacrimal bones. The orbital roof is formed in its anterior region by the orbital pars of the frontal bone and in its posterior region by the lesser wing of the sphenoid bone. In its medial region, it is formed posteriorly by the horizontal and vertical plate of the olfactory fossa (lamina cribosa), fovea ethmoidalis, and crista Galli. In its anteromedial region are the frontal sinuses. The orbital roof region hosts two fossae: the lacrimal fossa is anterolateral, and the trochlear fossa is anteromedial. Its medial region has two osseous features: the supraorbital foramen and the supratrochlear notch.[36,38]

The orbital floor is formed by the orbital pars of the zygomatic, palatine, and maxillary bones from the lateral to medial. In its medial portion travels the nasolacrimal duct. The infraorbital foramen, the extraconal exit point of the infraorbital nerve (V2), exits through the inferior orbital fissure and subsequently passes through the infraorbital sulcus. Finally, the orbital floor forms the roof of the maxillary sinus.[13,15]

The greater wing of the sphenoid bone and the frontal process of the zygomatic bone form the lateral wall. The sphenoid ridge on its lateral edge separates it from the orbital roof in its posterior region. The bony features found on the lateral wall are the lacrimal foramen and zygomatic orbital.[32]

The medial wall is formed anteriorly to posteriorly by the frontal process of the maxilla, the lacrimal bone, the ethmoidal pars, and the sphenoid body. The medial wall houses the nasolacrimal duct and contains the following bony features: the anterior and posterior ethmoidal foramina, found at the junction of the orbital roof with its medial wall in the frontoethmoidal suture.[2,8]

The optic foramen, located on the superomedial surface of the orbital apex and medial to the anterior clinoid process, is separated from the sphenoid ridge by the posterior root of the lesser wing of the sphenoid bone. Its medial border limits the sphenoid body, the superior portion borders the anterior root of the lesser wing of the sphenoid wing, and laterally, it is limited by the optic strut.[6]

The inferior orbital fissure is delimited anteriorly by the orbital pars of the maxilla, laterally by the zygomatic bone, and medially by the sphenoid body.[31]

Muscle relationships

The lateral rectus muscle (LRM), IRM, MRM, and SRM emerge from the AT, forming a cone surrounding the intraconal and extra-annular neurovascular structures. The main orbital muscles of interest in the inferomedial aspect of the orbit are the IRM, MRM, and SOM.[34]

The SRM is directed superoanterior and attaches to the sclerotic surface posterior to the cornea. The trajectory of the LRM is in the topography of the greater wing of the sphenoid bone. The inferior oblique muscle (IOM) emerges from the orbital floor in a posterolateral direction, passing between the IRM and the orbital floor.[13,34]

The IRM emerges from the AT and has an oblique trajectory, with its medial border superior to the lateral portion of the orbital floor. The SOM originates from the superomedial periorbit to the optic canal with an anterior trajectory to a tendon in the frontal trochlear fossa. Subsequently, it travels posterolateral below the SRM and inserts into the sclera between the SRM and LRM.[37]

Arterial relationships

The OA emerges from the internal carotid artery in its first subarachnoid segment on the dorsal portion of the carotid siphon just below the ON, entering the optic canal within its sheath and intra-annular, enters the orbital apex inferolateral to the ON where a recurrent meningeal branch usually emerges passing posteriorly from the sphenoid ridge into the adjacent dura mater. It is essential to mention that in 80% of cases, the OA has a superolateral trajectory to the ON. Subsequently, it has a projection between the SRM, SOM, and MRM, giving rise to the anterior ethmoidal artery (AEA) and posterior ethmoidal artery (PEA), pass through their respective foramina toward an intracranial trajectory.[21]

OA gives rise to a myriad of branches: the central retinal artery, short and long ciliary arteries, palpebral artery, lacrimal artery, supraorbital artery, supra and infratrochlear arteries, nasal artery, and dorsal and muscular arteries.[18]

The central artery of the retina is the first branch to emerge from the OA, being medial to the ciliary ganglion; it has no anastomotic connections, so its lesion produces irreversible amaurosis. The ciliary branches run parallel to the short and long ciliary nerves inferior to the ON and travel toward the choroidal lining and ciliary processes. The AEA is more prominent in diameter than the PEA; they enter their respective foramina. Intracranially, the AEA gives rise to the anterior falcine artery. Both ethmoidal arteries supply the anterior and posterior ethmoid sinuses, the frontal infundibulum, and the anterior nasal cavity.[2,5]

Neural relationships

The neural structures of interest focus primarily on the ON and III CN. The optic nerve and its four segments (from anterior to posterior) are intraocular, intraorbital, canalicular, and intracranial. The shortest segment is the first (1 mm) inside the sclera (optic papilla), and the longest is the second portion (25 mm), which is the segment of most significant interest in this study.[9]

The ON enters the orbital apex in the middle region of the AT and is inferior to the levator palpebrae superioris and SRM. Its sheath fuses with the periorbit on the anterior aspect of the optic foramen. In its intraorbital topography, the ON is surrounded by adipose tissue and connective tissue. It has an inferior and lateral medial arrangement in the direction of the posterior margin of the eye.[9,22] Just as the disposition of the OA concerning the ON is super-lateral, so are those of the nasociliary nerve (intra-annular branch of the maxillary nerve) and the superior ophthalmic vein in the direction of the orbital apex.[29,33]

The oculomotor nerve enters the intra-annular orbit and immediately lateral to the optic strut. In its medial topography, the oculomotor nerve divides into an upper and lower trunk next to the trochlear and nasociliary nerves. The upper division has a trajectory lower than the insertion of the SRM to the AT, and its branches emerge superolateral to the ON and toward the lower border of the levator palpebrae superioris and SRM muscles. The inferior branch projects its inferomedial branches. At the orbital apex, it is divided into three branches: two are directed toward the IRM and IOM, and another branch passes inferomedial to the ON in the direction of the MRM.[17,19]

CONCLUSION

SMA and inferomedial approaches are reasonable pathways to access the orbit from the medial endonasal endoscopic perspective. That is why recognizing and dominating the rigorous anatomy surrounding the access route is crucial. These medial wall approaches have strict structures that must be recognized to limit potential risk injuries to vascular and neural structures. So that, in the scenario of an orbital tumor, trauma, or any other pathology, safe endoscopic surgery can be performed. Furthermore, the support structures, both muscular and ligamentary, should not be transgressed as much as possible.

Ethical approval

The Institutional Review Board approval is not required, as it is cadaveric study.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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