Compartmental Endoscopic Surgical Anatomy of the Inferior Intraconal Orbital Space

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Abstract

Objectives This study aims to define the endoscopic anatomy of inferior intraconal space, in terms of its neurovascular structures and relationship to fixed anatomic landmarks.

Design A cadaveric anatomical study was conducted.

Setting This study was conducted at an academic cranial base center.

Participants Cadaveric subjects have been investigated.

Main Outcome Measures After dissection of the inferior intraconal space, the number and position of ophthalmic artery (OA) and oculomotor nerve (OMN) branches to the inferior rectus muscle (IRM) were quantified relative to the fixed landmark of the posterior maxillary wall. The point where the OMN branch to the inferior oblique muscle (IOM) crossed the lateral IRM margin was quantified.

Results A total of 18 OA branches were identified with a mean $\pm$ standard deviation of 2.6 ± 0.53 branches. The mean distance of the OA branch insertion from the posterior maxillary wall was 7.11 ± 5.65 mm. The average number of OMN branches to the IRM was 1.63 ± 0.74 with a mean insertion distance of 1.88 ± 1.89 mm. The OMN branch to the IOM crossed the lateral IRM margin 5.38 ± 5.42 mm from the posterior maxillary wall.

Conclusions This cadaveric study quantifies the variability of two critical neurovascular structures salient to endoscopic approaches to the inferior intraconal space, the OMN, and OA contributions to the IRM. Knowledge of the interrelationship between these structures is essential in safe technique for dissection.

Keywords

- intraconal orbital anatomy
- oculomotor nerve
- ophthalmic artery
- endoscopic approach

Introduction

Since the introduction of endoscopic endonasal surgery for sinonasal inflammatory disease, endoscopic techniques have concomitantly expanded their role in approaches to the skull base and orbital lesions. The endoscopic approach has been accepted as an alternative to the traditional open craniofacial

resection for tumors in these locations.^{1,2} The external orbitotomy and orbitozygomatic craniotomy approaches offer wide access to the orbit; however, medial lesions remain difficult to access and open techniques require a transcutaneous or transconjunctival approach.^{3,4} Even with these open methods, lesions of the orbital apex remain difficult to access and

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visualize. The endoscopic endonasal approach to medially, and particularly inferomedially, located intraorbital lesions has been described to be a safe alternative.^{5,6} The advantages of this minimally invasive approach include improved cosmesis, less globe retraction, and a reduction in disruption of otherwise normal structures.^{7,8} Orbital tumors may arise either in the extraconal (i.e., outside of the muscle cone), or intraconal (i.e., within the muscle cone) space.⁴ While endoscopic approaches to the medial extraconal orbit have been described considerably; reports of access to the inferior intraconal space have been limited.^{5,7,9} One important reason for this has been a lack of comprehensive understanding of the relevant endoscopic anatomy of the region. Here, we present a detailed study of the endoscopic neurovascular anatomy of the inferior intraconal space, which builds upon previous work to create a conceptual compartmental endoscopic model of this region.¹⁰

Methods

This study was an institutional review board exempt endoscopic cadaveric study of eight orbits from four cadavers, of which two were preserved in formalin with latex injection. A complete maxillary antrostomy, ethmoidectomy, and sphenoidotomy were performed in all specimens by using a 0-degree endoscope. After removal of the lamina papyracea, extraconal orbital fat, and the orbital floor up to the infraorbital nerve, the medial rectus muscle (MRM), and inferior rectus muscle (IRM) were exposed. The IRM was retracted inferiorly and laterally. The intraconal fat was carefully removed while preserving major neurovascular structures supplying the MRM and IRM. All measurements were performed using an endoscopic ruler and were reported relative to the fixed anatomic landmark of the posterior maxillary wall. The distance from the posterior maxillary wall to their insertion on the IRM muscle was measured. The caliber of the OA branches (small [<0.5 mm], medium [0.5 – 1.0 mm], large [>1.0 mm]), position of the vessel (medial margin, midbelly, lateral margin) relative to the long axis of the IRM, and its location (medial or lateral) relative to the oculomotor nerve (OMN) were recorded. The OMN was identified in each orbit, and the number of dorsal branches and distance from the dorsal insertion to the posterior maxillary wall was measured. Also, the OMN branch to the inferior oblique muscle (IOM) was identified on the dorsal or lateral surface of the IRM. The point at which the nerve crossed from the dorsal surface of the IRM to the relatively more protected lateral margin was also measured.

Results

A total of 18 OA branches were identified within the eight orbits. The mean $\pm$ standard deviation number of OA branches to the IRM was 2.6 ± 0.53 (range: 2–3 branches). The average distance of the insertion of the OA branches from the posterior maxillary wall was 7.11 ± 5.65 mm (range: 1–20 mm) (**Fig. 1A, B**). Seven branches were located along the medial IRM margin, nine were located in the midbelly position, and two were located along the lateral margin. The mean distance of the insertion of the OA branches from the posterior maxillary

wall was greater in the vessels in the midbelly (9.89 ± 6.48 mm) compared with those along the medial margin (4.29 ± 3.35 mm) (**Fig. 1B**). Ten of the arterial branches were of small caliber, eight were medium, and none were of large caliber. Among all the OA branches, 15 were medial to the OMN insertion while 3 were lateral to the OMN insertion.

The inferior division of the OMN was positively identified in each of the dissected orbits. The mean distance from the dorsal insertion of the OMN to the posterior maxillary wall was 1.88 ± 1.89 mm (range: 0–6 mm). The mean number of dorsal branches was 1.63 ± 0.74 (range: 1–3 branches). The mean distance from the posterior maxillary wall to the point at which the OMN branch to the IOM crossed the lateral margin of the IRM was 5.38 ± 5.42 mm (range: 0–14 mm) (**Fig. 1C**).

Discussion

Oculomotor Nerve Anatomy

The OMN travels through the superior orbital fissure through the lateral compartment of the annulus of Zinn (AOZ), known as the oculomotor foramen.^{10,11} As it enters the orbit, the OMN branches into the smaller superior division, which supplies the motor neurons to the superior rectus and levator muscles, and into the larger inferior division, which supplies the MRM, IRM, and the IOM.¹² The inferior division of the OMN also gives off a small branch which joins the ciliary ganglion inferolateral to the optic nerve (ON). The inferior division runs anterior and lateral to the ON within the intraconal space and further branches. Our findings indicate that the branches to the IRM can extend up to 6 mm anterior to the posterior maxillary wall and tend to be lateral to the OA contributions to the IRM. The branch to the IOM splits from the main trunk of the nerve almost immediately and travels along the lateral surface of the IRM to enter the IOM. We found that this branch may be exposed along the dorsal surface of the IRM for up to 14 mm before diving laterally. These findings suggest that manipulation of the inferior rectus muscle within 14 mm of the posterior maxillary wall could put either the IRM and/or the IOM branches of the OMN at risk of injury.

Ophthalmic Artery Anatomy

The OA can be divided into four segments as it courses from the optic canal to the orbit. The first portion extends from the optic canal, where it travels inferior and lateral to the ON, to the point where the artery turns medially. The second portion extends from this point to the next bend where the artery projects anteriorly and starts to travel above or below the ON. The third portion is where the artery turns medially, with 66 to 81% traveling over the ON, and 19 to 34% under the ON.^{11–14} The fourth portion is where the artery turns forward and runs anteriorly, medial to the common border of the superior oblique muscle, and MRM.¹⁰ The inferomedial muscular trunk (IMT) of the OA supplies the medial rectus and IRMs. We found that the vessels supplying the IRM may extend up to 20 mm from the posterior maxillary wall and are predominantly located along the medial margin and midbelly portion of the IRM.

The venous system is complex and highly variable. The endoscopic endonasal visualization of the superior ophthalmic

Fig. 1 (A) Endoscopic view of the right inferior intraconal space in the cadaveric dissection. The oculomotor nerve (OMN) trunk (black arrow) is emanating from the orbital apex at the level of the sphenoid sinus (SS) face. The inferior rectus muscle (IRM) is retracted inferiorly to reveal the OMN branch to the inferior oblique muscle as it splits from the main trunk almost immediately distal to the apex. The branch crosses to the lateral aspect of the IRM and travels along the IRM. Note the distribution of the ophthalmic artery (OA) branches as they supply the IRM. (B) Illustration of the dorsal surface of the IRM demonstrating the general pattern of OA branch insertion on the IRM. Each hash mark measures 5 mm, demonstrating the range of OA branch insertion points from the posterior maxillary wall. (C) Illustration of the dorsal surface of the IRM demonstrating the variability of the location at which the OMN nerve branch to the IOM crossed to the lateral margin of the IRM. Each hash mark measures 5 mm, with the farthest location of the OMN branch crossing at 14 mm. (D) Illustration of the anatomy of the inferior intraconal space with neurovascular supply to the IRM and MRM dividing the space into four conceptual zones, A1, A2, B, and C. Zone A1 is the safest area for retraction and dissection of the inferior rectus muscle because it is devoid major neurovascular structures. Zone A2 is bordered by the inferomedial muscular trunk of the OA as depicted. In this location, the OA and OMN branches to the IRM may still be in play and can be injured by excessive retraction or dissection. PMW, posterior maxillary wall.

vein is extremely challenging and requires extensive dissection above the ON.¹¹ The inferior ophthalmic vein branches run within the inferior orbital fissure and the superior orbital fissure. The medial ophthalmic vein is of concern in the endoscopic approach and exists in 40% of the population.¹² It arises in the superomedial orbit and runs extraconally along the medial side of the MRM.¹¹ Notably, the central retinal vein is not always identified, but should be spared, as it directly drains into the cavernous sinus.¹¹

Integrated Compartmental Endoscopic Anatomy

The inferior intraconal space is bounded superiorly by the ON and its associated neurovascular structures, including the nasociliary nerve, OA, and long ciliary artery and nerve. It is bounded inferiorly by the IRM. The posterior boundary is the AOZ; however, functionally, access is limited past the point at

which the inferomedial trunk of the OA crosses from a lateral position to a more medial position.¹⁰ The lateral and anterior boundary is also limited by visibility and accessibility with angled endoscopes and instruments behind the globe. These boundaries reflect the functional constraints of the endoscopic endonasal approach formed by critical structures, which can be injured if not anticipated.

In our previous work, we identified three zones within the medial intraconal space based on the neurovascular anatomy which predicted the anticipated surgical complexity of dissecting within these areas.¹⁰ In this schema, zone A represented the region anterior to the IMT of the OA and inferior to the midbelly of the MRM. This zone traverses the medial intraconal space and can be extended to include the inferior space as well. Based on the findings of the present study, we can now further refine this schema to divide zone A into A1 and A2 segments (—Fig. 1D).

Zone A1 represents the inferior intraconal space between the area 20 mm anterior to the posterior maxillary wall and the posterior globe. This is the safest area for retraction and dissection of the inferior rectus muscle as it is devoid of the OMN and OA branches to the IRM. The reported distance from apex to the posterior globe is approximately 26 mm; therefore, this provides for a small area of low-risk dissection.¹⁵ Furthermore, in this area, the OMN branch to the IOM has crossed the lateral border of the IRM and is also therefore protected from injury (→ Fig. 1C).

Zone A2 represents the area subtended by the IMT and an imaginary coronal plane 20 mm anterior to the posterior maxillary wall. In this location, the OA and OMN branches to the IRM may still be in play and can be injured either by excessive retraction or aggressive dissection. As the majority of the OA branches are medial to the OMN, these vascular arcades may be identified intraoperatively to serve as a lead to the nerve and as additional protection for the nerve.

As previously reported, zone B is the intraconal space anterior to the IMT and superior to the midbelly of the MRM, delineated by an imaginary line drawn through the middle of the long axis of the MRM.¹⁰ Zone B is superior to zone A and directly adjacent to the ON, anterior and posterior ethmoid arteries. Therefore, zone B anatomy is more complex than zones A1 or A2 due to its proximity to these vital structures.¹⁰

Zone C is the intraconal region within the orbital apex posterior to the IMT of the OA and represents a confluence of the medial and inferior intraconal spaces. This zone is the most technically challenging with high risk for injury to major neurovascular structures given the proximity of the AOZ, ON, and proximal OA.

Our goal was to survey the cadaveric anatomy and create boundaries to provide a conceptual guide for endoscopic dissection within the inferior intraconal space. We previously described the boundaries of zone A, and here we further divide the inferior intraconal space into two zones based on the anatomical complexity.¹⁰ Based on our dissection, zone A1 is the safest because of the limited neurovascular structures in this area and dissection becomes riskier within zone A2, where OA and OMN branches reside. The danger in dissecting within zone B lies in the risk of inadvertent injury to the ethmoidal vessels with potential for bleeding and retraction of the vessel into the orbit, leading to the orbital hematoma. A thorough understanding of the anatomy through an endoscopic approach is beneficial for both surgical planning and minimizing complications.

Conclusions

Our findings extend the compartmentalization concept of the medial and inferior intraconal spaces. We have delineated two zones within the inferior intraconal space based on the location of the OA and OMN branches to the IRM and their attendant risk of injury during endoscopic orbital approaches. While these findings may be used as a general

guide, the neurovascular anatomy within this region may be highly complex and variable. Consequently, comprehensive understanding of the anatomy, meticulous surgical technique, and collaborative efforts between rhinologic and oculoplastic surgeons should always be applied when tackling pathology within this area.

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