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Endoscopic Transorbital Approach to the Cavernous Sinus Lateral Compartment (Anatomical Cadaver Study)

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ABSTRACT

AIM: To determine whether the endoscopic transorbital (ETO) approach could be an alternative and a safer route to access the cavernous sinus (CS) lateral compartment.

MATERIAL and METHODS: ETO technique was studied on 3 cadavers and 6 CSes of these cadavers. Endoscopic dissection was visualized with a 0-degree angle endoscope and recorded with fiberoptic cable, light source and camera system and digital video recording system.

RESULTS: Superior orbital fissure (SOF), optic canal (OC), anterior ethmoidal artery (AEA) and posterior ethmoidal artery (PEA) foramens were visualized with periorbital dissection. Anterior wall of CS was reached after drilling the optic strut (OS). When the wall was opened, CS lateral and anteroinferior compartments were visualized. Internal carotid artery (ICA) were visualized from proximal ring to the last 2 cm of paraclival carotid artery. Cranial nerves (CNs) within the CS and the course of the interclinoid ligament were revealed.

CONCLUSION: The transorbital endoscopic method is an alternative approach to other techniques for accessing the lateral and anteroinferior compartments of CS. The advantages, disadvantages and limitations of the technique have been determined.

KEYWORDS: Transorbital, Lateral compartment, Anteroinferior compartment, Optic strut, Superior orbital fissure

ABBREVIATIONS: EETS: Endoscopic endonasal transsphenoidal surgery, **ETO:** Endoscopic transorbital, **CSF:** Cerebrospinal fluid, **CS:** Cavernous sinus, **TONES:** Transorbital neuroendoscopic surgery, **SOF:** Superior orbital fissure, **OC:** Optic canal, **AEA:** Anterior ethmoidal artery, **PEA:** Posterior ethmoidal artery, **OS:** Optic strut, **ON:** Optic nerve, **CN:** Cranial nerve, **ICA:** Internal carotid artery, **DI:** Diabetes insipidus

INTRODUCTION

In recent years, there have been significant advances in minimally invasive procedures for the skull base. Nowadays, endoscopic surgery is used more frequently in most surgical specialties; in particular, endoscopic endonasal transsphenoidal surgery (EETS) is used instead of the conventional transsphenoidal microsurgery technique in many centers. Endoscopic techniques compete with transcranial techniques in terms of outcome, although they reduce surgical morbidity in selected patients (7,9).

Recently, an endoscopic transorbital (ETO) approach has been used in various intracranial lesions and cerebrospinal fluid (CSF) leaks (10,14,16). A group of new surgical techniques has been defined as transorbital neuroendoscopic surgery (TONES) (15). In these techniques, the superior eyelid route has been presented as an alternative route for anterior and middle skull base pathologies (15,18). However, accessing the cavernous sinus (CS) through this approach still seems difficult (4).

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This study aimed to determine whether the ETO approach could be an alternative and a safer route to access the CS lateral compartment.

MATERIAL and METHODS

This study was conducted by examining three cadavers and the six CSes on both eyes of these cadavers. The cadavers had no history of cranial surgeries, and the presence or absence of silicone injection was examined and recorded in terms of the quality of the injection and the strength and elasticity of the tissues.

Using a workstation in the laboratory, each cadaver was fixed on the tabletop in the supine position. Endoscopic dissections were performed using a 4 mm in diameter and 14 cm in length rigid endoscope with a 0-degree angle and recorded using a digital video recording system.

Surgical Technique

Skin Stage

The superior eyelid approach was applied to the cadavers (Figure 1).

As described in previous studies, the orbicularis muscle was cut to retract the skin-muscle flap superolaterally until the frontal orbital bone rim was seen after the curved incision made from the eyelid fold (2,12). The frontal orbital rim was drilled 3 mm from the anterolateral part in front of the lacrimal fossa.

At this stage, the important point to consider was that the supraorbital notch and supraorbital nerve passing through it as well as the skin-muscle flap of the vessels should not be damaged.

Periorbital Dissection Stage

After the periost was cut, subperiosteal followed by subperiorbital dissection was continued until the superior aspect of superior orbital fissure (SOF) was seen. Then, the process was continued with the endoscope. The optic canal (OC) is located medial to the SOF (Figure 2).

Medially foremost, the first foramen seen was the foramen of the anterior ethmoidal artery (AEA). Moving forward, the smaller foramen found more posteriorly was the foramina of the posterior ethmoidal artery (PEA). As the dissection was continued, the medial OC and lateral SOF were seen posteriorly.

Optic Strut Stage

After the dissection was completed, the optic strut (OS) located between the SOF and OC was exposed and drilled with a 2-mm tip high-speed drill. In this OS drilling stage, the medial edge of the SOF and small wing of the sphenoid bone were drilled together toward the frontal base to prevent damage to the optic nerve (ON) and other cranial nerves (CNs) emerging from the SOF as well as to expand the manipulation area (Figures 3 and 4 A,B).

CS Stage

The CS has a complex anatomy (5). Therefore, understanding the anatomy of the CS in three dimensions is important to achieve successful surgical results in these lesions (19). The CS has four spatial compartments, namely, superior, lateral, anteroinferior, and posterior (1).

The structure encountered when the OS is completely drilled is the CS anterior wall (Figure 5). When the anterior wall is

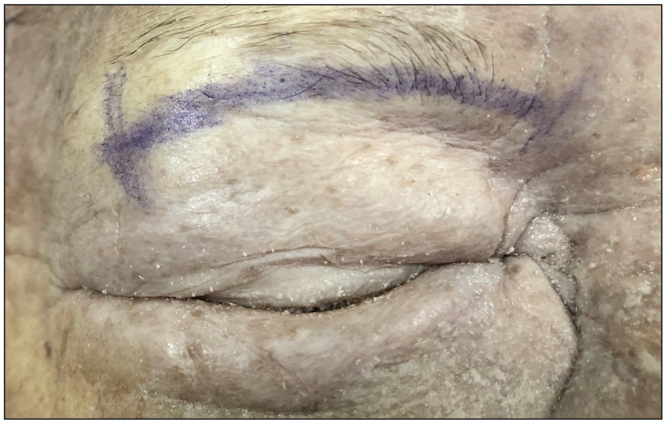

Figure 1: Incision line of the superior eyelid approach in the right eye.

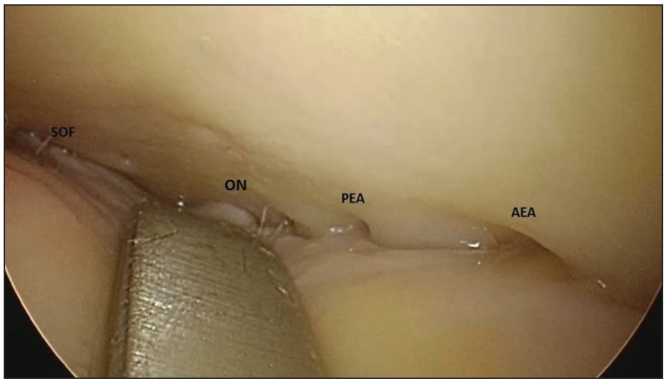

Figure 2: Appearance of the superior orbital fissure, optic nerve, and posterior and anterior ethmoidal arteries in the periorbital dissection stage of the right eye.

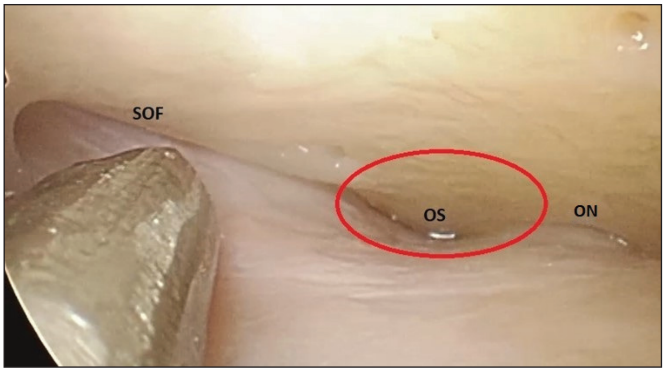

Figure 3: Optic strut between the right eye superior orbital fissure and optic nerve.

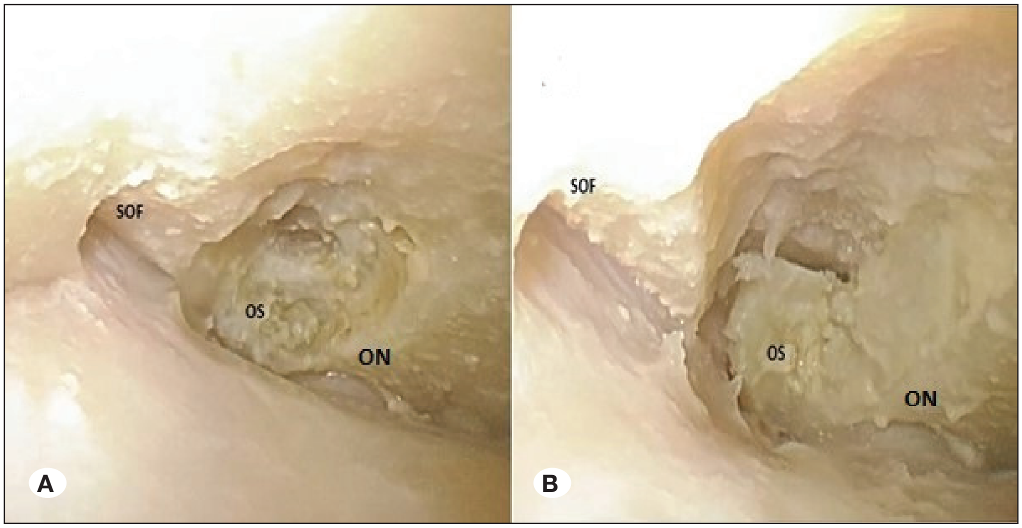

Figure 4: Right eye optic strut drilling stage **A)** Widening of the drilling area toward the frontal bone **B)** Deeping moment at the optic strut drilling stage. The connection between the superior orbital fissure and the optic strut is decoupled.

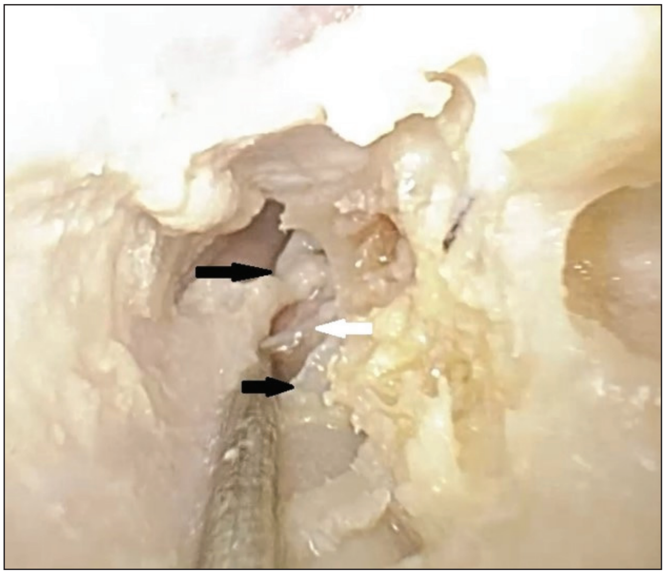

Figure 5: Cavernous sinus anterior wall (indicated by black arrows) exposed after the optic strut was drilled. White arrow indicates the anterior bend of the internal carotid artery.

opened, the last part of the paraclival carotid artery and the intracavernous segment of the internal carotid artery (ICA) with the proximal ring emerge. The anteroinferior compartment, lateral compartment, fibrous bands, and CNs within the CS were imaged.

RESULTS

The most important finding in the skin stage of all cadavers is the necessity of drilling the frontal orbital rim in front of the shallow lacrimal fossa. It was demonstrated that the rim should be rounded by a minimum of 3 mm to prevent the orbital rim from obstructing the endoscope-holding angle.

Subperiosteal and subperiorbital advancement of the dissection during the periorbital dissection phase and securing the tissues as much as possible was shown to be very important for the later stages. Any opening in these tissues results in periorbital adipose tissue coming out and obstructing the viewing area of the endoscope.

In all cadavers, the SOF, OC, AEA, and PEA foramens were seen at the same distance from each other. The distance between AEA and PEA, PEA and OC, OC and SOF were measured as 12 ± 2 mm, 5 ± 2 mm, and 7 ± 1 mm, respectively (Table I).

Table I: The Distances Between the Foraminas in the Orbit

	Distances between AEA – PEA (mm)		Distances between PEA – OC (mm)		Distances between OC – SOF (mm)	
	Left eye	Right eye	Left eye	Right eye	Left eye	Right eye
1st Cadaver	13	14	4	5	7	7
2nd Cadaver	11	12	6	7	6	7
3rd Cadaver	12	10	5	3	7	8

***AEA:** Anterior ethmoidal artery, **PEA:** Posterior ethmoidal artery, **OC:** Optic canal, **SOF:** Superior orbital fissure.*

It was demonstrated that in the OS stage, the OS, located between the SOF and OC, was anterosuperiorly and posteroinferiorly located. This shows that during the drilling of the OS, initiating the drilling more superiorly helped us to reach the anterior wall of the CS earlier.

Drilling the OS alone was not enough for the manipulation of the CNs. The necessity of drilling the OC ceiling with the medial lower part of the SOF, which is considered to be the continuation of the OS, was revealed. Drilling a large area in this site was found to be beneficial in retracting the CNs laterally during the introduction of the CS. OS is a structure that expands from front to back, and its foremost orbital face is its narrowest part. For this reason, drilling should be done in this direction.

It was demonstrated that the last 2 cm of the paraclival carotid artery from the ICA proximal ring can be easily observed when the anterior CS wall is opened and the CNs that advance toward the SOF are removed laterally.

The trace of the 6th CN was seen in the lateral compartment of the CS, medial to the other CNs and lateral to the ICA (Figure 6 A,B).

Widespread fibrous bands fixing the ICA artery to the surrounding tissues were seen in all cadavers. Most of these fibrous bands were observed between the carotid artery and CS lateral wall (Figure 7). Concurrently, the interclinoid ligament was seen in the same path as and in front of the 3rd CN in all cadavers (Figure 8).

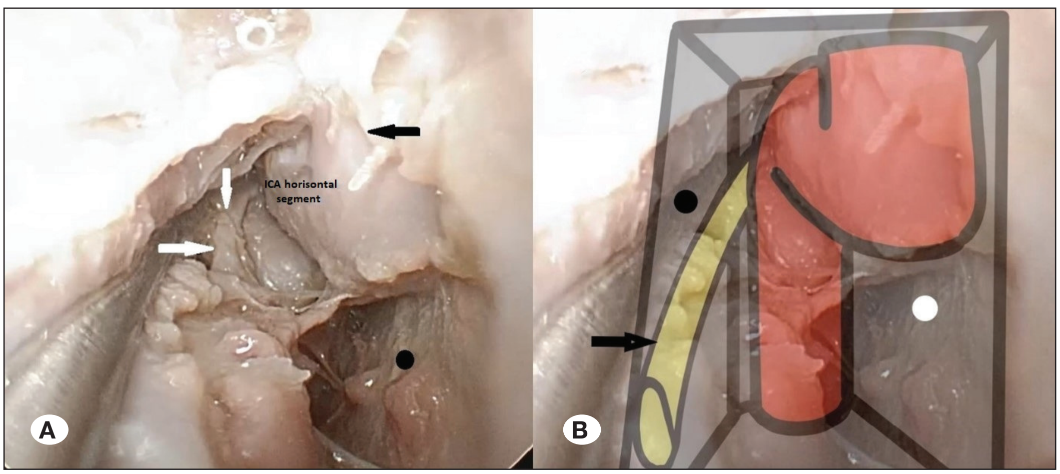

Figure 6: A) Course of the 6th cranial nerve in the lateral compartment of the cavernous sinus. Black arrow indicates the proximal ring, and black dot indicates the medial wall of the cavernous sinus. **B)** Drawing image of the same figure. An intracavernous segment of the internal carotid artery is seen. White dot, black dot, and black arrow indicate the cavernous sinus medial wall, cavernous sinus lateral wall, and 6th cranial nerve, respectively.

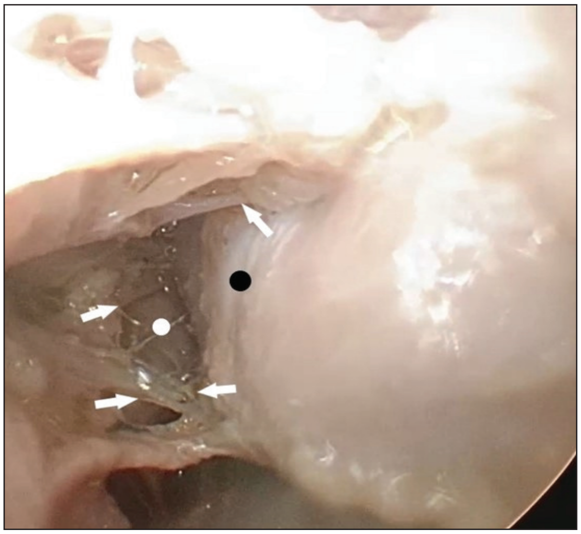

Figure 7: Dense fibrotic bands (indicated by the white arrows) within the right cavernous sinus. The black dot indicates the horizontal segment of the internal carotid artery, and the white dot indicates the paraclival carotid artery.

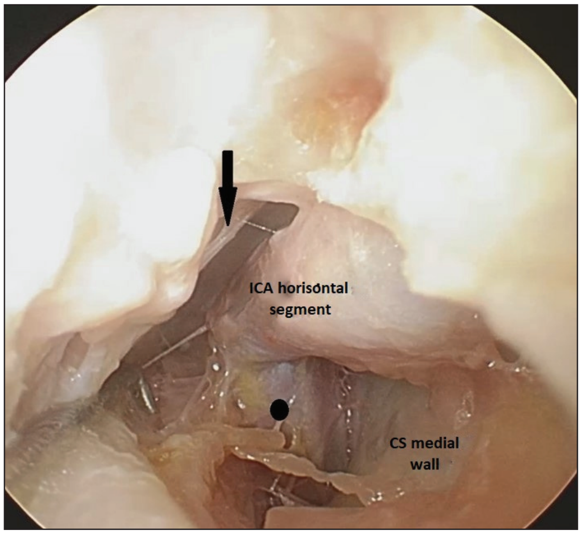

Figure 8: Endoscopic imaging of the right anteroinferior and lateral compartment. The black arrow indicates the interclinoid ligament, and the black dot indicates the paraclival carotid artery.

Figure 9: The 4th cranial nerve (right eye) dissected from the surrounding structures. The black arrow indicates the hook.

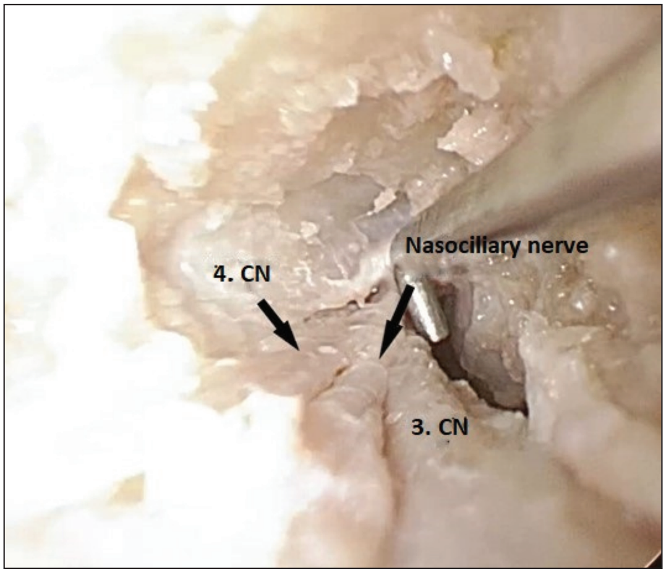

Figure 10: Distribution of the cranial nerves (right eye).

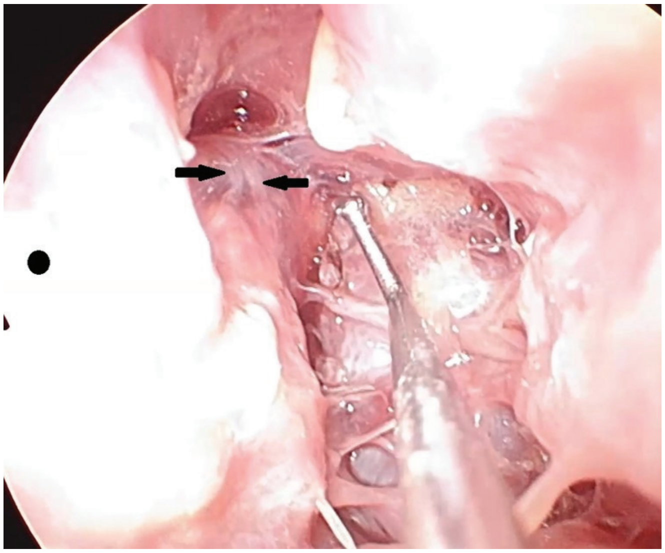

Figure 11: Sympathetic fibers on the horizontal segment in the transorbital dissection from the left orbit (Black arrows). Black dot indicates the internal carotid artery intracavernous anterior vertical segment.

During its course in the CS, the 4th CN, which is more inferior to the 3rd CN, was observed in the superolateral level at the exit from the SOF. When the nerve fiber was traced, it was found to be distributed into the fibers of the superior oblique muscle. Observing the 4th CN in the CS could not be achieved due to our angle and the covering of the 3rd CN.

In the image where we observed the conditions of the nerves at the moment of exit from the SOF, the nasociliary branch of the 5th CN, which is thinner medially, starting from the 4th CN, and the third CN, which is seen as the thickest of them, was revealed as the most medial (Figures 9 and 10).

When the ICA was retracted medially, sympathetic fibers that were easily observed especially on the horizontal segment were revealed (Figure 11).

DISCUSSION

ETO is an alternative route to the CS lateral and anteroinferior compartments in selected patients. Although its applicability has not been proven, our study has shown that it is possible to access the lateral compartment of the CS with this approach.

There are studies on CS anatomy in which both transcranial and endoscopic endonasal approaches have been applied (11,13,17). With advances in medicine, invasive methods are being replaced with minimally invasive methods. However, the important point to note is that the results of the less invasive procedures should be as effective and successful as those of the invasive methods. In the field of neurosurgery, using the endoscopic technique has advantages such as higher resection rates and lower mortality and morbidity rates in sellar region tumors compared to transcranial techniques (6,8). Although experience in CS surgery is high, especially in tumors involving the lateral compartment, and despite the developments and advantages in EETS, the resection rates are still quite low (1).

With the new studies, many pathologies around the orbit can be reached and excised with the ETO approach (3,20).

When the orbital anatomy is well known and understood, it is an important landmark for the OS transorbital approach, which can be reached with simple dissections. This is because it is possible to reach between the CS lateral wall behind the OS and the ICA intracavernous segment when viewed from lateral to medial with an endoscope at an angle of 45 degrees. Thus, it is less retracted than the transcranial approach, which would reduce the complication rates such as CN palsy.

Until more experience is gained, the structures that can be confused with the OC are the AEA and PEA foramina. It should be kept in mind that these foramina are the first structures that are encountered in medial dissection. Therefore, their order and the approximate distance between them must be known. Considering that it is the OS, drilling performed from the OC medially (between the OC and PEA or AEA) will lead to an insertion into the nasal cavity and further back into the sphenoid sinus instead of the CS.

The second most important landmark is the SOF. Drilling the medial edge of the SOF in the OS drilling stage is an important step, as it saves space for manipulation. However, attention should be paid to the CNs during this drilling phase. It should be known that the sheath emerging from the SOF is the continuation of the CS lateral wall and contains the CNs. The medial edge of the SOF is also a very thin bony structure; therefore, care should be taken against the risk of breakage during lapping. In the clinical approach, this procedure may cause CN paralysis in the postoperative period, as it may obstruct the CNs at the SOF level.

Using the endoscopic technique antorbital has created a new approach to access the CS. The anterior wall of the CS was excised and the ICA anterior bend, anteroinferior compartment, lateral compartment, and lateral wall were exposed. Compared to other techniques, it is thought that the endoscopic technique makes it easier to reach the anteroinferior and lateral compartments.

In addition, it is also thought that tumors in the CS, which we access through this route, can be easily excised. Since the entire intracavernous segment of the ICA, except the tumor, can be visualized with this technique, it can also be considered as a technique suitable for clipping aneurysms that may occur in this segment, especially with the dome facing laterally (Table II).

Although it is possible to reach the anteroinferior compartment simultaneously with the lateral compartment, it is predicted that it would be easier to evacuate tumors that have invaded the lateral and anteroinferior compartments. With EETS, for such tumors, it would be necessary to open the CS medial wall and even the CS anterior wall before the exact location of the ICA can be detected in the vast majority of cases. However, there is no requirement to open the medial wall in the transorbital approach. In addition, during the opening of the CS anterior wall, as in EETS, a situation such as not being able to determine the exact location of the ICA will not be important due to the incision to be made between the ICA and the lateral wall.

Table II: Indications for Using the Endoscopic Transorbital Approach

Tumors	Pituitary adenoma Cavernous sinus meningioma Chordoma Craniopharyngioma
Bone tumors and diseases	Osteoma Fibrous dysplasia Paget's
Vascular diseases	ICA intracavernous aneurysm

***ICA:** Internal carotid artery.*

In addition to these advantages, the enlargement of the lateral and anteroinferior compartments of the tumor will also ensure safety. Since the area to be inserted in the CS will expand, risks such as CN or large vessel injury will be reduced. In fact, this rate will be even lower in patients with preoperative CN involvement.

In our study, the presence of fibrous bands, which firmly attached the ICA cavernous segment to the surrounding structures, were shown. It has been observed that these bands may prevent the surgeon from accessing the CS. However, since these fibrotic bands will be fragmented in a CS invaded by the tumor, the stability of the carotid artery will be impaired, and the tumor will expand to this area.

Although the ETO approach is suggested to have a low risk of complications, the most important complications that can occur with the approach include ON damage, damage to other CNs, and ICA injury. In order to reduce the risk of developing complications, the OS should be drilled with small-sized drills and with slow movements as much as possible. Blunt movements should be avoided as much as possible during the opening of the CS anterior wall to reduce the risk of ICA injury.

Nerve injuries cannot occur only by retraction. Injury to the ophthalmic artery, which passes from the OC along with ON, may cause total blindness in the patient, as it leads to impairment in the blood flow to the central retinal artery.

Despite these risks, the risks found in standard EETS (such as CSF leakage, pituitary insufficiency, temporary and permanent diabetes insipidus (DI), epistaxis, anosmia, and hyposmia) are either minimal or non-existent.

The most common clinical complication is enophthalmus, because the easiest mistake associated with this technique is not staying at the subperiorbital position during dissection and causing periorbital fat to come out. The periosteum in the periorbital region is easily fragmented because it is a weak layer. To avoid this complication, it should be proceeded with gentle dissection as much as possible. In addition, periorbital connective tissue that is damaged during dissection should be sutured in such a way as to prevent the leakage of fatty tissue, and the integrity of the globe circumference should be preserved.

The ETO technique is a new technique even for neurosurgeons who have experience working with the endoscope. Therefore, as with any technique, it will require an adaptation process. An advantage of these new anatomical studies is to gain experience for an ETO approach that can be applied clinically. A better knowledge of the anatomy of the region can be accomplished by comparing the new and older studies.

The major limitation of this study is the small number of cadavers. Increasing the number of variations will eliminate this limitation. However, new clinical studies are needed because cadavers do not exactly replicate a patient's clinical condition.

CONCLUSION

The transorbital endoscopic method is an alternative approach to other techniques for accessing the lateral and anteroinferior compartments of CS. Its main advantages are the lower risk of complications compared to other techniques, and it is easy to perform. Its major drawbacks include limited knowledge of the endoscopic anatomy of the intraorbital structures for neurosurgeons and lack of experience with regard to the transorbital technique.

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