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Transorbital approaches to the skull base: an overview

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Introduction

Skullbase surgery has evolved significantly over the years. In particular, the approaches to the ventral skull base have been completely revolutionized by the advent of endoscopic endonasal approaches (EEA)[1-3]. The paramedial aspect of the anterior and middle skullbase, particularly the areas lateral to the internal carotid artery (ICA) and optic nerve (ON), has, however, remained a major limitation to the endoscopic ventral skullbase approaches[4]. Nevertheless, the EEA was the beginning of a revolution in the field of skull base surgery. Three main factors have likely contributed to this changing trend. Firstly, the general trend of minimalism that has affected all specialties of surgery played a key role. Cosmesis, better patient comfort, and quality of life issues have influenced the neurosurgeons too and compelled us to rethink. A better understanding of the disease biology, as well as the advent of several non-surgical options, including stereotactic radiosurgery, have also contributed to this paradigm shift. The second factor that contributed to this change is the adoption and acceptance of the neuroendoscope as a visualization tool in neurosurgery. The third contributor has undoubtedly been the unrelenting efforts to learn and understand the anatomy and anatomical corridors of the skull base.

The transorbital approaches (TOAs) have been a natural progression in our pursuit to refine skullbase approaches, and hence represent the contemporary philosophy of skullbase surgery, which emphasizes targeted exposure, the use of technology to address pathology, and the maximally effective utilization of adjuvant treatments to ensure a high quality of life for patients. The original concept of transorbital approaches was introduced by Kris Moe in 2007[5].

Approaches involving the orbit in some form are not new in neurosurgery. These can be described as cranio-orbital or orbito-cranial, depending on the need[6-9]. A transorbital approach, by definition and in a strict sense, is an orbito-cranial approach performed through the orbit without removing the orbital margin[7]. The term "endoscopic transorbital approach" (ETOA) encompasses several endoscopic surgical routes through the orbit that allows access to different lesions in the anterior and middle cranial fossae. Understanding the anatomical landmarks and relationships in these regions is essential for the safe and effective use of the transorbital approach in surgical interventions. The goal is to access the paramedian ventral skull base and beyond, especially orbital pathologies, and all three cranial fossae.

Advantages and disadvantages

The advantages of this approach include reduced morbidity, no visible scarring or external craniotomies, and minimal brain manipulation. The TOA may be used in isolation or in combination with other minimally invasive techniques or even in conjunction with stereotactic radiosurgery. Therefore, based on the patient age, medical co morbidity and the disease biology, these approaches may allow individualised treatment alternatives in complex skullbase conditions. The requirements for a surgeon include a good understanding of the orbital and nasal anatomy, comfort with the endonasal endoscopic surgeries and critical analysis of the preoperative imaging modalities. Above all, the ability to correctly select the case is the single most important decision defining the success of the TOA.

Anatomical essentials of the orbit

The orbit is a pyramidal structure with its apex pointing posteromedially towards the optic canal[8]. The complexity of this conical structure may be understood by the fact that as many as seven bones come together to form its roof, floor, medial, and lateral walls. The frontal lobe of the brain lies above the roof, which is made by the orbital plate of the frontal bone and the lesser wing of the sphenoid. The orbital process of the palatine and maxillary bones, along with contributions from the sphenoid, form the orbital floor, separating it from the maxillary sinus below. The lateral wall of the orbit is formed by the greater wing of the sphenoid, along with the frontal and zygomatic bones, which separate the orbit from the overlying temporalis muscle. The medial wall of the orbit, which separates it from the nasal cavity, is formed by the body of the sphenoid and lacrimal bones, with contributions from the frontal process of the maxilla and the thin part of the ethmoid bone called the lamina papyracea.

Primary target areas for transorbital approaches and indications

The various transorbital approaches that create a minimally invasive route have evolved from treating primary orbital pathologies to becoming a technique for accessing extradural and intradural skull base lesions, especially when combined with other endonasal or craniofacial approaches[7]. It allowing direct access to several orbital and deep cranial targets while minimizing morbidity compared to traditional transcranial routes includes:

1. Orbit and Periorbital region: this includes extraconal lesions such as Spheno-orbital meningiomas and benign and malignant orbital tumors
2. Anterior cranial fossa: Olfactory groove, cribriform plate and adjuvant intracranial tumors may be reached through the trans orbital route, especially endoscopically[7].
3. Middle Cranial fossa: The approach allows surgeons to address lesions such as those in Meckels cave, the cavernous sinus, and the lateral sphenoid wing.
4. Cavernous sinus: Both cadaveric and clinical literature emphasize access to the cavernous sinus, as well as structures like the superior orbital fissure, foramen rotundum, and foramen ovale, by offering direct visualization and resection possibilities.
5. Temporal lobe and Mesial structures: Some advanced multiportal techniques permit access to the mesial temporal lobe and the insular region,
6. Petrous apex and Posterior cranial fossa: Selected transorbital routes reach the petrous apex and even parts of the cerebellopontine angle, expanding the potential for combined approaches in complex pathologies.

Levels of difficulty and rationale

TOA is a technically demanding and narrow exposure. Hence, there are significant learning curve issues. One of the key requirements to master this approach is to have a good experience with EEA. The reasons are several and include similarity of instrumentation, acquaintance with the limitations of working in narrow corridors and getting used to using the endoscopic vision to complete the work[7].

In order to allow a graduated upscaling of surgeries done through the TOA and minimise complications in the learning process[10], suggested five levels of difficulty for the TOAs. The anatomical essentials, pathologies to be treated and transorbital surgical skills necessary were categorised to define these levels and thoroughly described. These levels can be summarised as follows:

Level I: includes addressal of the extradural pathologies, extraconal pathologies and CSF leaks. These require extraconal exposure, extradural anterior and middle cranial fossa and one can hone the surface exposure skills.

Level II: involves intradural anterior and middle fossa approach that helps one master dural opening, intradural dissection and repair. Spheno-orbital meningiomas fall in this category.

Level III: involves intraconal, middle fossa interdural Meckel's cave approach and intradural temporal pole approaches that allow resection of intraconal tumors, trigeminal schwannomas and parenchymal temporal lobar lesions.

Level IV: Once level III is accomplished, the next group of cases that may be taken up include optico-carotid lesions, cavernous sinus lesions and mesial temporal lesions. The typical lesions that this level refer to are anterior clinoid meningiomas and mesial temporal sclerosis

Level V: includes petrous apex and posterior cranial fossa approaches which, according to the authors, is the hardest level. The pathologies that come within level include petroclival meningiomas and chrondrosarcomas.

Variations of TOA

There are four types of transorbital approaches (discussed later) depending on the tangential relationship of the approach with the globe and the adjoining orbital wall. Of these, the superior eye lid transorbital approach (SETOA) is the most commonly employed approach[11], described a modular classification of the SETOA and attempted to contexualise this classification as per the levels of difficulty described above. They essentially classified two types of SETOAs namely a standard and an extended approach.

The standard approaches include drilling of the frontal process of the zygoma (lateral orbital wall), the greater wing of the sphenoid, drilling of the sagittal crest and division of the meningo-orbital band. The extended approach, as per this classification, involves a superficial extension like a lateral orbitotomy (LO) or a superolateral orbitotomy (SLO) to improve the instrument maneuverability or deeper extensions to enhance surgical exposure at the target like anterior clinoidectomy, middle cranial fossa floor flattening and anterior petrosectomy.

As per the authors, the majority of the level I and II pathologies can be addressed by a standard SETOA while levels III-V require some sort of extension. While the deeper extensions are naturally required to address the pathology at hand, the superficial extensions, provide some key advantages in deeper pathologies of higher level of complexity and include more lateral to medial range of movement on the surface which helps to reach targets located at awkward angles, lesser retraction on the globe while working deep and the SLO in particular allows a retractor to come in to hold the temporal lobe that maintains the corridor while looking deeper.

Technical considerations

TOA is usually performed endoscopically and is referred to as eTOA or TONES. This is essentially an endoscope assisted approach, and the aim is to create a coplanar endoscopic surgical channel. The narrow approach is negated by the magnified and panoramic vision of the pathology.

Any of the four walls of the orbital wall may be used for this approach and depending on that, the e-TOA may be any of the following four variants [7]:

1. The superior eyelid crease (SLC),
2. Precaruncular (PC)
3. The lateral retrocanthal (LRC), and
4. The preseptal lower eyelid (PS).

Therefore, based on the target in the base of the skull, these approaches allow access to the pathology with minimal disruption of the access areas and the related brain.

Superior eyelid crease

It is by far the most commonly used transorbital approach[12]. It exposes the superior part of the orbit, frontal sinus, anterior skull base, supraorbital, posterocentral regions of anterior cranial fossa and lateral part of middle cranial fossa. It has an advantage of using natural skin crease in upper eyelid for lesser scarring post operatively. **Figures 1-6** demonstrate the operation room set up, case example, step by step demonstration of the TOA and radiological outcomes.

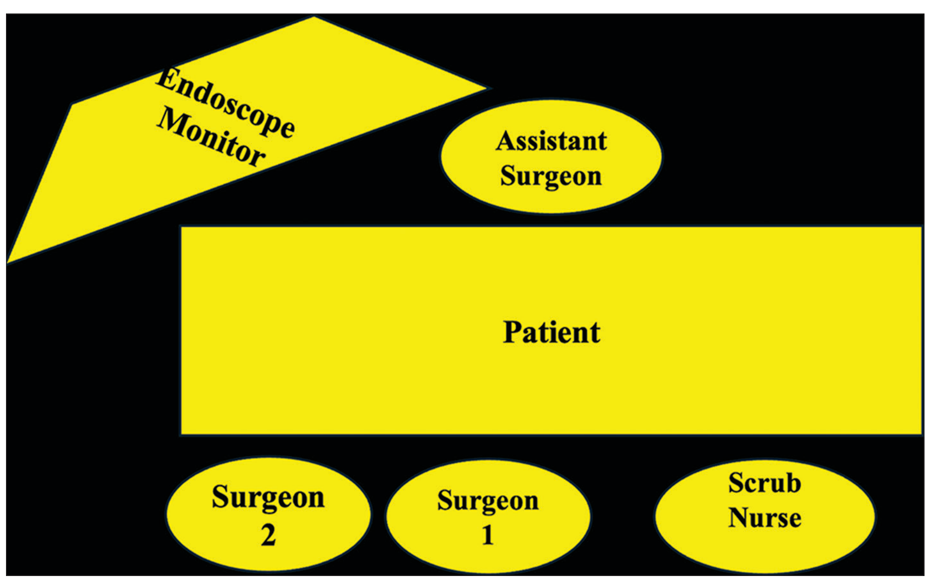

Figure 1: Shows the OT set up for a superior eyelid TOA

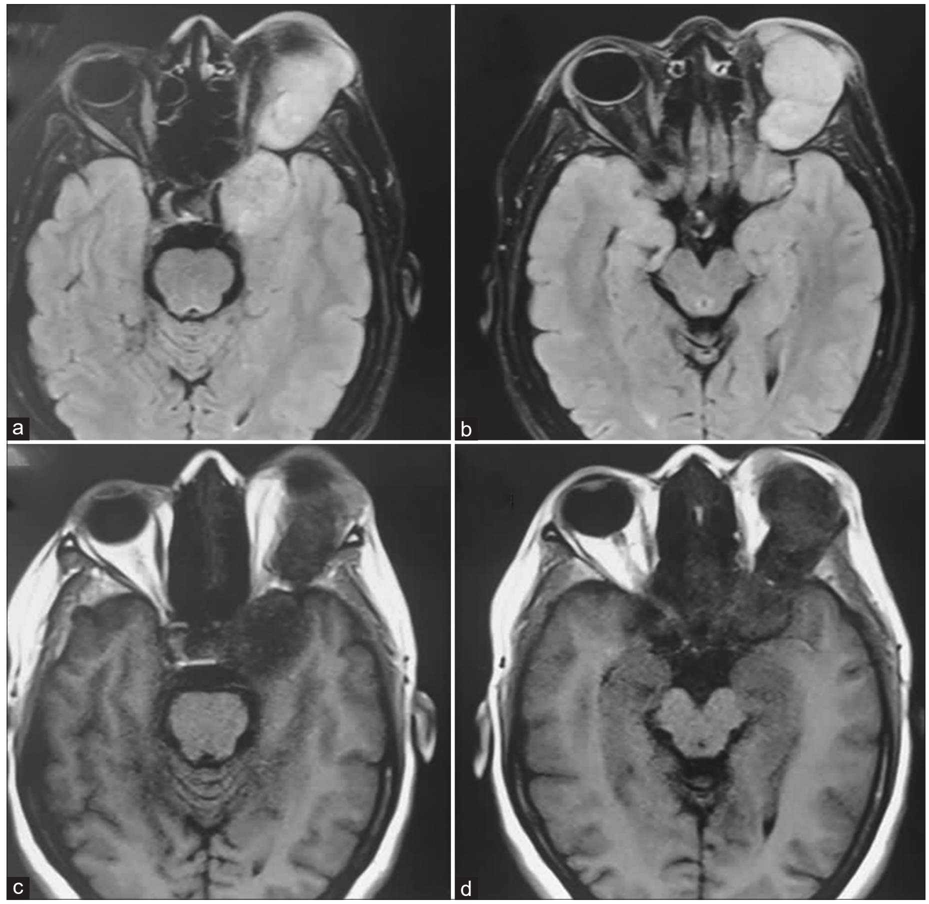

Figure 2: Shows the axial T2 flair (a,b) and T1 (c,d) images of a left orbito-cranial tumor occupying the superolateral aspect of the left orbit with middle fossa extension. Proptosis of the left eye is appreciated. Imaging features are suggestive of a trigeminal (V1-division) schwannoma

It can be divided into four stages for understanding namely:

1. **The skin phase:** This phase of surgery is usually done with the naked eyes, but loops can be very useful. The incision is a horizontal one along the upper eyelid crease. It is important to dissect in the appropriate anatomical layer. One has to divide only the palpebral portion of the orbicularis oculi but stay superficial to the "white plane" formed by the superior tarsal plate, orbital septum and the levator pelpebris superioris muscle. Along this plane, lateral orbital rim is palpated and a bone deep incision is made to become subperiosteal. Sutures are placed to keep open the eyelid exposure.

   Following the plane between the periorbital and the periosteum of the orbit, the globe is retracted medially and one creeps along the lateral orbital wall to reach deeper structures. The IOF is usually visualised first. Exposure of the SOF takes more effort.
2. **Working space:** The working space is necessary to manoeuvre instruments inside the orbit. There are some steps which are mandatory while others are optional. The mandatory step is drilling the body of the zygomatic bone forming the lateral wall of the orbit. This drilling must expose the temporalis muscle. This way, one can achieve a greater freedom of movement of the instruments. Division of the meningo-orbital band that forms the lateral most end of the SOF further adds to the medial orbital retraction. This point is also important for further orientation. The drilling of the zygomatic body is continued towards the posterolateral wall of the orbit formed by the greater wing of the sphenoid (GSW). Typically for the working space creation, only the lateral part of the GSW needs to be removed leaving behind the medial part called the sagittal crest. This exposes the temporal dura. The subsequent steps depend on the eventual target. Two more steps may be optionally added to access deeper structures and optimise instrument angulation and include a lateral orbital rim osteotomy or a superolateral orbitotomy.

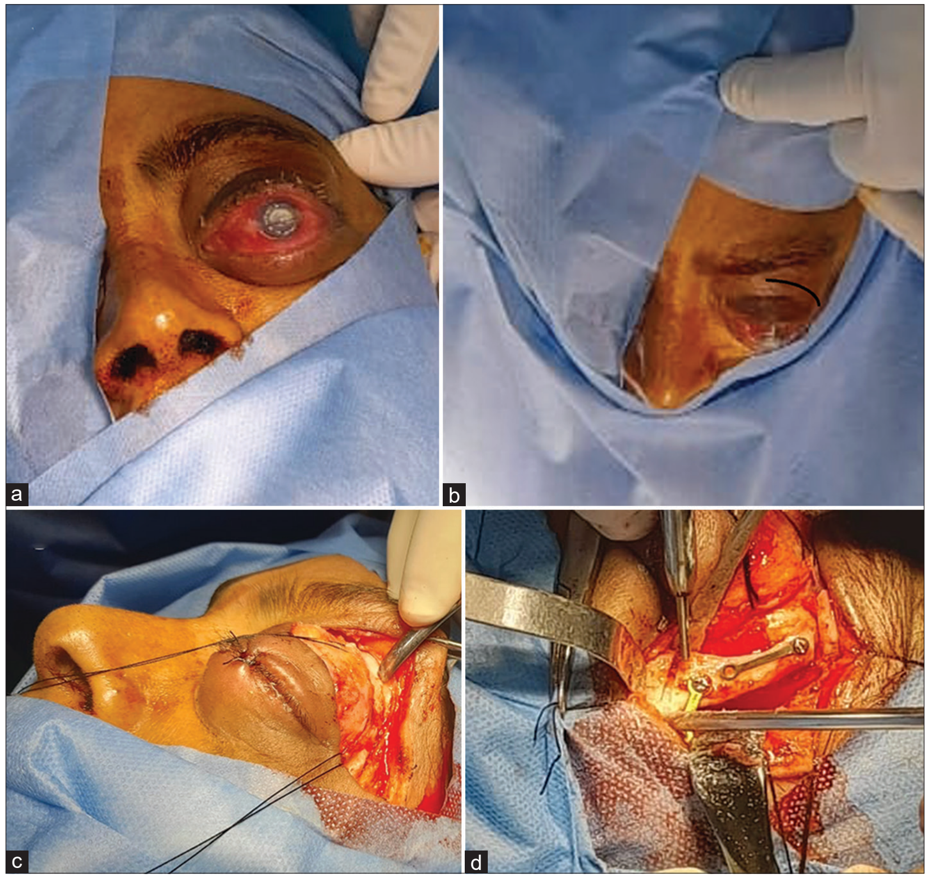

Figure 3: Intraoperative photographs show the exposure related changes of the cornea and the conjunctiva (a). A superior eye lid incision mark is shown (b). Exposure of the orbital margin is shon (c) as well as our technique of first placing miniplates before completing orbital rim osteotomy when needed (d)

3. **Additional lesion directed exposure:**
   With the aforementioned exposure, it may be possible to remove extraconal pathologies as well as extra-intradural lesions like sphenoorbital meningiomas[14]. However, for deeper pathologies starting from the proposed level 3 exposures and beyond, a series of additional bony drilling must be performed in a modular fashion[12,13] have systematically described these additional anatomical bony regions as follows:
   A. **Lesser wing of sphenoid (LSW):** This drilling is started after the GSW has been drilled in the working space phase and frontobasal bone has been drilled. The LSW is the first and a key bony landmark that is related to the subsequent bony pillars. With the drilling of this horizontal strip of bone, the frontobasal and pretemporal dura are exposed. Duratomy is this area gives access to both regions and the sylvian fissure.
   B. **Sagittal crest:** This is the second deep bony pillar. It is the triangular part of the GSW, oriented sagittaly and located medially. It is a relatively newly described landmark and a very very important one. The SC is drilled from the apex till the base until the maxillary strut and the foramen Rotundum are exposed. This exposure is key to start cavernous sinus lateral wall dural peeling and expose anteromedial temporal dura. Thus access to the cavernous sinus, trigeminal schwannomas and the mesial temporal lobe requires taking down the SC.
   C. **Anterior clinoid process:** The next important bony pillar is the ACP. This is nothing but a medial continuation of the LSW above the SOF. Optic canal unroofing and egg shell drilling of the ACP in its direction allows the ACP to be delivered out. At this stage of surgery, a hand held doppler may be useful to locate the position of the internal carotid artery. Following this exposure, duratomy allows inspection of the optico-carotid area.
   D. **Middle fossa floor:** This fourth internal bony pillar is the middle fossa floor. This requires extradural elevation of the temporal lobe to visualise the floor and the

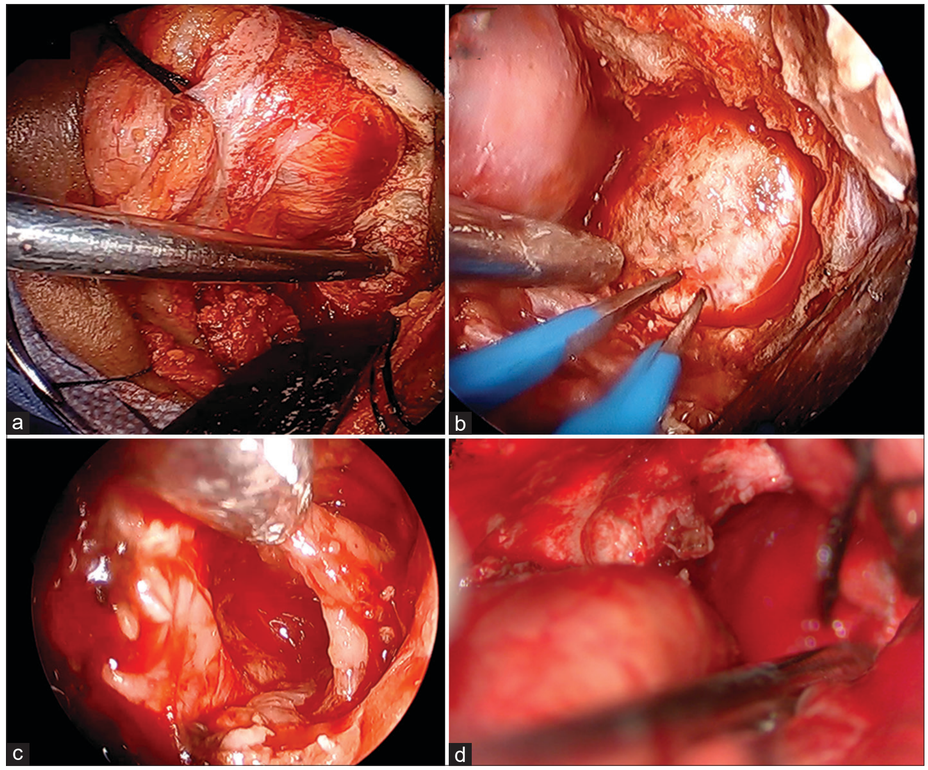

Figure 4: Shows the deepening of the skin incision to expose the orbital rim and inner side of the lateral orbital wall by a sub periosteal route (a). Removal of the GSW has exposed the tumor in the interdural plane of the middle fossa (b). The periorbita was opened and the orbital portion (c) and then the middle fossa portion (d) were removed

foramen spinosum with the middle meningeal artery. The middle fossa floor may be drilled to access the infratemporal fossa.

E. **Petrous apex:** The petrous apex is the fifth and most deep bony pillar that needs to be drilled to access the posterior fossa. Since this is a posteromedial target accessed through the TOA, a better angulation of instrument assembly requires supero-lateral drilling of the GSW near the pterion. Anterior petrosectomy is conducted using the standard landmarks[16]. The drilling commences from medial to lateral direction.

4. **Closure:** A multilayered closure with autologous tissue is preferred. Fascia lata onlay with fat along the surgical tract with or without fibrin glue application is a routine policy at our centre. The orbital rim, if removed, needs to be replaced and fixed with miniplates. The skin closure is done in two layers; the deep muscular layer is closed with vicryl while the skin is closed with prolene sutures.

Figure 7 shows pre and postoperative images of a case of sphenoorbital meningioma, a common indication treated by TOA.

Other variants of the TOA are as follows:

Pre-caruncular approach

Caruncle is fleshy, pink structure occupying the medial canthus[17]. Medial canthus is held to the lacrimal bone by the medial canthal tendon which also encloses the lacrimal sac. The medial orbital part is opened to have direct, bloodless plane to access medial orbital roof, lamina papyracea, ethmoidal arteries, cavernous sinus, parasellar and paraclinoid internal carotid artery, optic nerve and the central anterior skull base [18]. The incision is placed over the conjunctiva overlying caruncle – skin junction at the apex of the medial canthus. Dissection further behind the Horner's muscle and posterior limb of medial canthal tendon gives an avascular plane after incising the periorbita from the crista lacrimalis. The corridor is between periorbita and medial orbital wall. Identification and preservation of lacrimal sac is necessary. Blunt dissection is performed to recognize the ethmoidal foramens and structures passing through it. When posterior ethmoidal

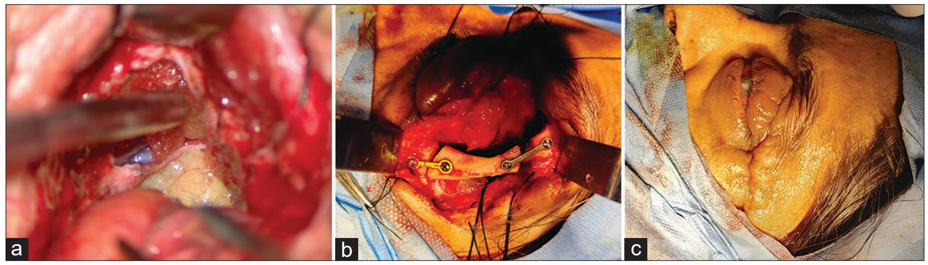

Figure 5: Shows the closure steps. The middle fossa cavity was packed with fat while surgicel was layered over the retroorbital cavity (a). The lateral wall orbitotomy is being fixed with miniplates (b). This allowed expansion of the superficial working space. The skin was closed in layers (c)

artery is reached, caution execution is essential as the optic nerve is 7 mm posterior to it. The dissection can be continued till orbital apex. Fronto-ethmoidal suture indicates the level of anterior skull base. Once drilling and tumour excision is done, the conjunctiva is approximated with absorbable sutures. It has better cosmesis because of completely hidden conjunctival scar. Following lesions are suited for this approach: Medial orbital wall and apex lesions., ethmoid sinus lesions, medial orbital wall fracture, medial rectus or intraconal masses.[19]

Lateral retro canthal approach

This approach provides access to the greater sphenoid wing, deep lateral orbit, orbital apex, lateral aspect of the ACF, MCF and infratemporal and temporal fossa[7]. The incision is just posterior to the insertion of lateral canthus in the conjunctiva over the lateral orbital rim. It can be combined with pre septal lower eyelid approach for better accessibility to inferolateral pathologies. The subperiosteal dissection is carried out between inferior orbital fissure till the orbital roof along the lateral orbital wall. Superior orbital fissure is identified posteriorly whereas the optic canal is mostly hidden. For only greater sphenoid wing exposure, drilling posterior to the zygomatic bone between inferior and superior orbital fissures would suffice. MCF, temporal and infra temporal fossae are reached by removing greater sphenoid wing [5]. The spheno-frontal suture makes the border for lateral frontal and middle cranial fossa craniectomies, when performed superior and inferior to the suture respectively. This way the sylvian fissure can also be reached. Closure is by re approximating periosteum and loose skin sutures. The indications for this approach are:

1. Lateral orbital wall and apex lesions
1. Lateral intraconal tumour
2. Lateral wall fracture
3. Sphenoid wing and middle cranial fossa pathology
4. Maxillary sinus, infra temporal and anterior temporal lesions

Pre-septal lower eyelid approach

It provides access to the orbital floor, maxillary sinus, inferior orbital fissure and foramen rotundum[18]. The lower eyelid conjunctival incision is performed 2 mm below the tarsus and around 6 mm inferior to the eyelid margin. Orbicularis oculi is identified along with inferior orbital septum and the periosteum over the orbital rim is incised. Dissection is undergone subperiosteally above the orbital floor. Further dissection may proceed by sectioning the infraorbital bundle and IOF. It is a safe approach for superficial tumour or trauma. Common indications are:

1. Anterior orbital mass
2. Inferior orbital fracture
3. Orbital decompression

A brief review of literature[9,15,20,23-30] enlisting the results of large clinical experiences with TOAs is presented in **Table 1.**

Potential complications and limitations

Despite making a fascinating entry into the world of skullbase surgery, it should be remembered that this approach has its own share of complications. The exposure is very narrow and instrument maneuverability is very much restricted. As such, the lesser experienced surgeons may struggle with hemostasis, adequate pathology

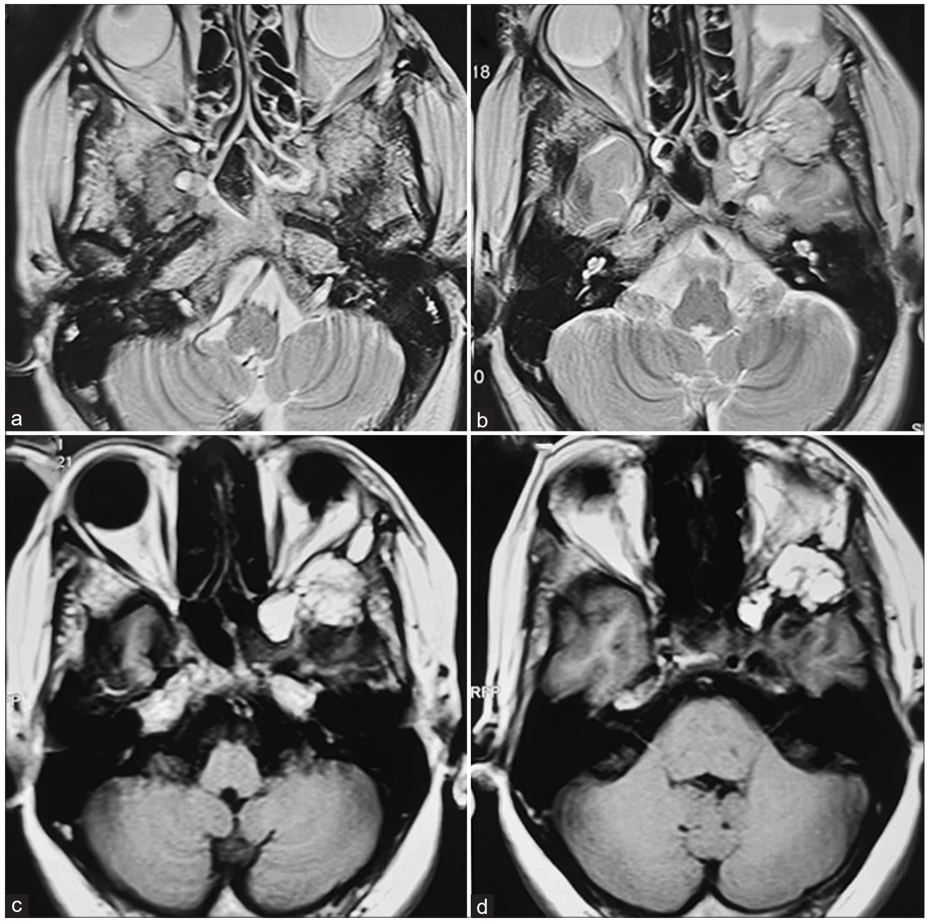

Figure 6: Postoperative T2 (a,b) and T1 (c,d) images show a complete tumor resection, resolution of the proptosis and fat packed in the middle fossa surgical cavity

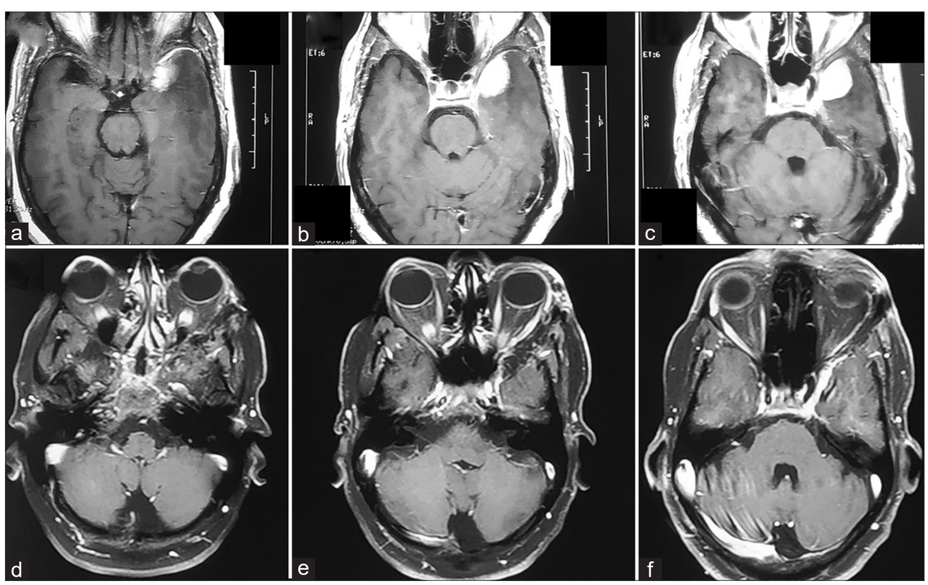

Figure 7: Shows the left sphenoorbital meningioma with intense enhancement and dural tail. There is no encasement of the ICA or tumor extension inside the cavernous sinus (a-c). The tumor was resected using a left TOA and the postoperative scans show a complete tumor resection (d-f) with completely healthy temporal lobes

dissection and bimanual dissection. All of these could lead to suboptimal outcomes and complications[20-22]. The complications specific to each of the four different types of TOA are enumerated below:

Table 1: Literature review of large clinical series on transorbital approaches

Author	Year	Technique	Study topic	Cases	Results	Complications
Feller *et al.*[9]	2023	Superior eyelid crease	Transorbital approach for resection of intracranial skull base lesions: Outcomes and complications	40	multidisciplinary	Infection (1), hematoma (1), Seizure (1)
Di Somma *et al.*[23]	2023	Superior eyelid crease	Complications of the Superior Eyelid Endoscopic Transorbital Approach to the Skull Base: Preliminary Experience With Specific Focus on Orbital Outcome	20	5 spheno-orbital meningiomas, 1 intradiploic Meningioma, 2 intraconal, 1 temporal pole lesion, 2 trigeminal schwannoma, 3 cavernous sinus lesions, and 6 petroclival lesions	Diplopia (6), periorbital edema (3)
DS Kong *et al.*[24]	2020	Superior eyelid crease	Optimal indications and limitations of endoscopic transorbital superior eyelid surgery for spheno-orbital meningiomas	41	eTOA+lateral orbital rim osteotomy=GTR , especially enplaque variety	CSF leak (2), wound dehiscence (2)
Park *et al.*[25]	2020	Superior eyelid crease	Comparative Analysis of Endoscopic Transorbital Approach and Extended Mini-Pterional Approach for Sphenoid Wing Meningiomas with Osseous Involvement: Preliminary Surgical Results	24	minimally invasive exposure than eMPTA	CSF leak (1), diplopia (1), ptosis (1)
Goblin *et al.*[26]	2019	Superior eyelid crease (8), retro caruncular (2), lateral retrocanthal (1), upper medial (1)	Biopsy and resection of skull base tumors using transorbital endoscopic approaches: primary results	12	Needs interdisciplinary approach	Transient CNV1 hypoesthesia (2), transient ptosis (1)
Lee *et al.*[27]	2018	Superior eyelid crease	Endoscopic Endonasal Versus Transorbital Surgery for Middle Cranial Fossa Tumors: Comparison of Clinical Outcomes Based on Surgical Corridors	21	GTR: TOA > EEA	Decrease in visual acuity (1), CN V neuropathy (2), CN VI neuropathy (2), ptosis (3) keratitis (2)
DS Kong *et al.*[28]	2018	Superior eyelid crease	Clinical and ophthalmological outcome of endoscopic transorbital surgery for cranioorbital tumors	18	7-GTR,7-NTR,4-ST Considered good option	CSF leaks (2), transient lateral rectus muscle paresis (2), transient ptosis (3)

Contd...

Table 1: Contd...

Author	Year	Technique	Study topic	Cases	Results	Complications
Dallan *et al.*[15]	2018	Superior eyelid crease	Endoscopic Transorbital Superior Eyelid Approach for the Management of Selected Spheno-orbital Meningiomas: Preliminary Experience	14	4 combined with endonasal route, Safe approach	Upper eyelid necrosis (1), diplopia (3), CNV_2 hypoesthesia (3), CNV_1 hypoesthesia (1), palpebral edema (3)
Lim *et al.*[29]	2012	Superior eyelid crease, pre caruncular	Transorbital Neuroendoscopic Management of Sinogenic Complications Involving the Frontal Sinus, Orbit, and Anterior Cranial Fossa	13	epidural abscess via the Superior eyelid crease approach, mucocele via pre caruncular approach	Nil
Balakrishnan *et al.*[30]	2011	Superior eyelid crease, pre caruncular	Applications and outcomes of orbital and transorbital endoscopic surgery	107	no difference in surgical success rates with transnasal and transantral medial orbital wall and orbital floor repair and cerebrospinal fluid leak repair.	Diplopia (14), persistent vision change (3)
Baseoglu *et al.*[20]	2010	superior eyelid crease	The transorbital keyhole approach: Early and long-term outcome analysis of approach-related morbidity and cosmetic results	71	Excellent cosmesis	CSF collection (5), facial palsy (2), hyposphagma (2), periorbital hematoma (2), subdural hematoma (1)

Superior lacrimal crease

1. Limited exposure for deep orbital apex lesions
2. Ptosis risk if levator palpebrae superioris is damaged/ incised.
3. Risk of damage to lacrimal gland, optic nerve is present.
4. Sensory loss in forehead/ upper eyelid.
5. If closure is not meticulous, cosmetic disfigurement of eye is a possibility.

Precaruncular

1. High risk of lacrimal sac injury and cause epiphora.
2. Medial rectus injury can cause diplopia.
3. Ethmoidal artery injury can lead to hematomas.

Lateral retrocanthal approach

1. Injury to lacrimal gland, lateral rectus muscle
2. Temporary weakness of forehead due to injuring frontal branch of facial nerve

Preseptal approach

1. Lower eyelid temporary numbness
2. Lower eyelid ptosis

Conclusion

The TONES is an exciting addition to skullbase surgery. It is very contemporary, scientific study based and tailored approach to select skullbase pathologies. However, it has a significant learning curve issue and mandates the surgeon to first master the EEA and then graduate through different levels of difficulty of TOAs. This approach is not a replacement to the available surgical approaches and one has to guard against its indiscriminate usage.

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