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11 The Transorbital Endoscopic Approaches

Alberto Daniele Arosio, Pierlorenzo Veiceschi, Elisa Maria Lazzari, Iacopo Dallan, Davide Locatelli, and Paolo Castelnuovo

Abbreviations

ACF	Anterior cranial fossa
AEA	Anterior ethmoidal artery
CSF-L	Cerebrospinal fluid leakage
CT	Computed tomography
DWI	Diffusion-weighted imaging
EEA	Endoscopic endonasal approaches
ETA	Endoscopic transpalpebral approaches
FS	Frontal sinus
IEA	Inferior eyelid approach
IOF	Inferior orbital fissure
LRM	Lateral rectus muscle
MCF	Middle cranial fossa
MRI	Magnetic resonance imaging
ON	Optic nerve
PEA	Posterior ethmoidal artery
RAOS	Robotic-assisted orbital surgery
RMA	Recurrent meningeal artery

Davide Locatelli and Paolo Castelnuovo authors equally share the last authorship.

Daniele Arosio and Pierlorenzo Veiceschi authors equally contributed to the Manuscript and share the first authorship.

A. D. Arosio · E. M. Lazzari
Division of Otorhinolaryngology, Department of Biotechnology and Life Sciences, "Ospedale di Circolo e Fondazione Macchi", University of Insubria, Varese, Italy

P. Veiceschi
Division of Neurosurgery, Department of Biotechnology and Life Sciences, "Ospedale di Circolo e Fondazione Macchi", University of Insubria, Varese, Italy

I. Dallan
ENT Unit, Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy

Head and Neck and Forensic Dissection Research Center (HNS and FDRc), Department of Biotechnology and Life Sciences, University of Insubria, Varese, Italy

D. Locatelli
Division of Neurosurgery, Department of Biotechnology and Life Sciences, "Ospedale di Circolo e Fondazione Macchi", University of Insubria, Varese, Italy

Head and Neck and Forensic Dissection Research Center (HNS and FDRc), Department of Biotechnology and Life Sciences, University of Insubria, Varese, Italy

Research Center for Pituitary Adenomas and Sellar Pathology, University of Insubria, Varese, Italy

P. Castelnuovo (✉)
Division of Otorhinolaryngology, Department of Biotechnology and Life Sciences, "Ospedale di Circolo e Fondazione Macchi", University of Insubria, Varese, Italy

Head and Neck and Forensic Dissection Research Center (HNS and FDRc), Department of Biotechnology and Life Sciences, University of Insubria, Varese, Italy

Research Center for Pituitary Adenomas and Sellar Pathology, University of Insubria, Varese, Italy
e-mail: paolo.castelnuovo@uninsubria.it

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SEA	Superior eyelid approach
SOF	Superior orbital fissure
SOM	Spheno-orbital meningiomas
TONES	Transorbital neuro-endoscopic surgery

11.1 Introduction

The orbit is a challenging anatomical area which often requires invasive surgical approaches due to its restricted surgical accessibility. Nonetheless, considering its crucial location within the skull, it is a subject of shared interest among several surgical specialties, including neurosurgery, otorhinolaryngology, ophthalmology, and maxillofacial surgery.

A wide range of pathological conditions can involve the orbit as a surgical target, such as congenital or traumatic bony defects, Basedowian ophthalmopathy, vascular malformations, and neoplastic lesions (both intraconal or extraconal, benign or malignant in nature). Moreover, the orbit can act as a corridor to reach adjacent intracranial anatomical areas.

In the wake of a renewed interdisciplinary collaboration, technological advances, and greater experience by the operators, new pioneering techniques have been developed for the management of orbit pathologies [1, 2] . Orbital surgery has recently been revolutionized by the implementation of endoscopic assistance to both transnasal and transpalpebral approaches. According to anatomical studies and clinical experiences, the authors believe that endoscopic techniques can be integrated magnificently in orbital procedures, offering improved outcomes. Moreover, the value of the endoscope as a teaching tool should be overemphasized, considering that all the members of the operating room staff (e.g., nurses, physicians, residents, and students) share the same view of the first surgeon, thus improving the anatomical knowledge and speeding up the learning curve. These procedures, according to contemporary experiences, allow the achievement of optimal results in terms of radicality and aesthetic-functional outcomes [3–7] . The transnasal endoscopic route allows easy access to all the medial orbital compartment, from the lacrimal area to the orbital apex, without the need for any skin incision or retraction of the cerebral parenchyma. In the current state of the art, transphenoidal or transethmoidal endoscopic surgeries to the orbit have become well-codified procedures and have become widespread worldwide. They are often carried out in close cooperation between neurosurgeons and otolaryngologists [7].

As regards the endoscope-assisted transpalpebral approaches, the application in the literature is limited to case series and expert opinions [8]. However, the published experiences seem to demonstrate that these approaches represent a solid option not only to manage intraorbital lesions but also to use the orbit as a surgical corridor for selected skull base and intracranial pathologies [8–10] . Moe et al. have proposed the term “Transorbital Neuro-Endoscopic Surgery” (TONES) to indicate a group of procedures that use this operative corridor to access the skull base. Indeed, considering orbit as a corridor, it is possible to treat several disorders located into both the anterior and middle cranial fossa [10].

Based on these premises, in this chapter, we will present a review of endoscopic-assisted transorbital procedures, with particular emphasis on transpalpebral approaches, considering that transnasal transorbital approaches have been already described in a previous chapter. Indications, preoperative work-up, operating room setting, and surgical technique will be analyzed and valuable surgical tips will be provided in order to avoid complications. The importance of a multidisciplinary collaboration will be stressed out, as the key to guarantee optimal results while minimizing the risks associated with the single surgical procedure. Finally, postoperative work-up and follow-up will be discussed, along with some speculations regarding possible future improvements and evolution of these surgical approaches.

11.2 Preoperative Work-Up

An accurate preoperative work-up is required in the patient candidate for endoscopic transorbital surgical procedures, with particular reference to a precise radiological evaluation for evaluation of several factors (patients' individual anatomy, the relationship of the lesion with the herein located neuro-vascular structures, the invasion of different cranio-orbital compartments) and an accurate ophthalmological assessment.

11.2.1 Radiological Assessment

A head Computed Tomography (CT) scan is usually the first diagnostic exam performed. It allows for an accurate location of the orbital mass and a study of the endo-orbital structures, although with a lower contrast resolution as compared to Magnetic Resonance Imaging (MRI). A CT scan is generally well-tolerated by the patient, as it is fast and provides important clues useful for a presumptive diagnosis [11]. It represents the gold standard exam for traumas, helping to detect foreign bodies or fractures of the orbital frame. CT must be considered an indispensable first-level examination for the diagnosis of orbital malformations since it allows the study of both the bone component and other secondary alterations. Moreover, if an endoscopic intervention via the transnasal route is planned, CT imaging is paramount to highlight the presence of anatomical variants of the paranasal sinuses to properly plan the surgical procedure.

MRI of the orbit and the maxillo-facial region is also warranted before surgery. It provides better details for the orbital compartment due to its superior definition for soft tissues compared to CT scan and may detect finer pathognomonic characteristics of the lesion [12] . T1, T2, and T2*-weighted MRI sequences, along with time-dependent characteristic of the contrast-enhancement of the lesion, the use of diffusion-weighted imaging (DWI) and fat suppression sequences, provide presumptive indications about the nature of the mass, as well as a more precise localization along the intraconical or extraconical spaces, the involvement of the orbital apex, the extension to the intracranial compartments, and the relationship with the optic nerve [11]. MRI can be completed with a Magnetic Resonance Angiography to offer more precise diagnostic information about the vascular anatomy, to some extent comparable to angiography, without the need of invasive arterial catheterization. To conclude, both CT and MRI are complementary diagnostic exams warranted for patients undergoing endoscopic surgery. To note, the two exams can be merged to be used for intraoperative navigation, clinical and ophthalmological evaluation. The current body of literature shows a homogeneous consensus about the fact that an accurate ophthalmological evaluation should precede orbital surgery, as it detects signs of disease that may go unnoticed by non-specialist colleagues [13]. By checking measurable and repeatable parameters, it is possible to classify the severity of the presenting symptoms and compare it to the post-surgical outcomes. The execution of assessments such as visual field test, exophthalmometry, Hess Lancaster test is the cornerstone of ophthalmological consultation. Hertel's exophthalmometer offers an accurate and reproducible measurement of the degree of the proptosis, with the advantage of comparing both eyes in a single measurement. A difference of at least 2 mm in the two eyes or a value greater than 21 mm is considered pathological. A measurement of less than 14 mm is classified as an enophthalmos. The Hess Lancaster test is used to evaluate the binocular vision, and it is indicated for establishing the presence of diplopia or suppression. The advantage consists in the speed of execution. It is carried out with the aid of glasses with red and green filters.

11.2.2 Photographic Documentation

A photographic imaging of the candidate for transorbital surgery can be useful not only for the diagnosis and the treatment plan but also for the control of the results, to improve communication between colleagues, for didactic use and even for medico-legal issues. A standardized approach considering the main variables for the picture (e.g., patient positioning, lighting, exposure, background, depth of field) is suggested in order to have comparable preoperative and postoperative documentation.

Once all the appropriate investigations have been carried out, a multidisciplinary discussion between all members of the skull base team is performed. Finally, the surgical procedure is discussed with the patient, focusing on the risks and benefits of the specific surgery, and consent is obtained.

11.3 Intraoperative Setting

11.3.1 Patient Positioning

A correct positioning of the patient in the operating room is imperative for a safe and effective surgical procedure. The setting is dependent on several factors, mainly represented by the type and duration of surgery, anesthesiologic plan, specific devices required (e.g., intraoperative navigation). A proper placement should provide safety for the procedure to be performed as well as quick and adequate access to airway and circulation for the anesthesiologist, while providing comfort for the surgeons [14]. Transorbital surgery is performed in general anesthesia, with the patient placed in supine position with the occipital-nuchal region lying on a silicon headrest. Anesthesiologists are free to access the airways, venous lines, and other medical devices. The patient's arms are positioned laterally to the body and secured on armboards. The elbows are padded with foam to avoid ulnar neuropathy from pressure contact at the ulnar groove. Padding should also be retained under the heel area, and a pillow is placed behind the knees to reduce tension on the back. Usually, a slight anti-Trendelenburg's position is adopted, in order to reduce bleeding during the procedure. Rigid fixation with the Mayfield head-holder is unnecessary since it can limit manual adjustments to head position during surgery. Furthermore, it removes the discomfort produced by pin fixation. This frameless positioning allows the free usage of neuronavigation with electromagnetic tracking, with the non-invasive patient reference taped nearly 3 cm over the glabella and the flat emitter (StealthStation S8; Medtronic, Minneapolis, USA) positioned under patient's head [15].

11.3.2 Operating Room-Setting and Instrumentation

In the transorbital approach, the operating room is organized with one monitor in front of each surgeon (usually two monitors during standard procedures, sometimes three in case an adjunctive surgeon is needed). The first and second surgeons also have visual access to the intraoperative neuronavigation device for CT and MRI image-guidance, which can be used during various phases of the procedure (Fig. 11.1). The setting also need to take into account the eventual need for special surgical instrumentation such as Ultrasonic Aspirator devices or Cryoprobes [4] . The endoscope is never fixed with a holder, but held by one of the operators and, as a rule, surgical procedures are performed using a three- or four-handed technique [2]. Depending on the preferences of the surgical team, the first surgeon can hold the endoscope and one other instrument, while the other takes care of the second instrument and aspiration/irrigation; alternatively, the first surgeon can work with both hands while the second holds the endoscope. In the superior eyelid procedures, a third surgeon may be useful to maintain an adequate operating space by use of flexible retractors to displace the orbital content. This action has to be dynamic, that is providing alternatively moments of compression and retraction of the orbital content, so as to avoid mechanical or ischemic damages.

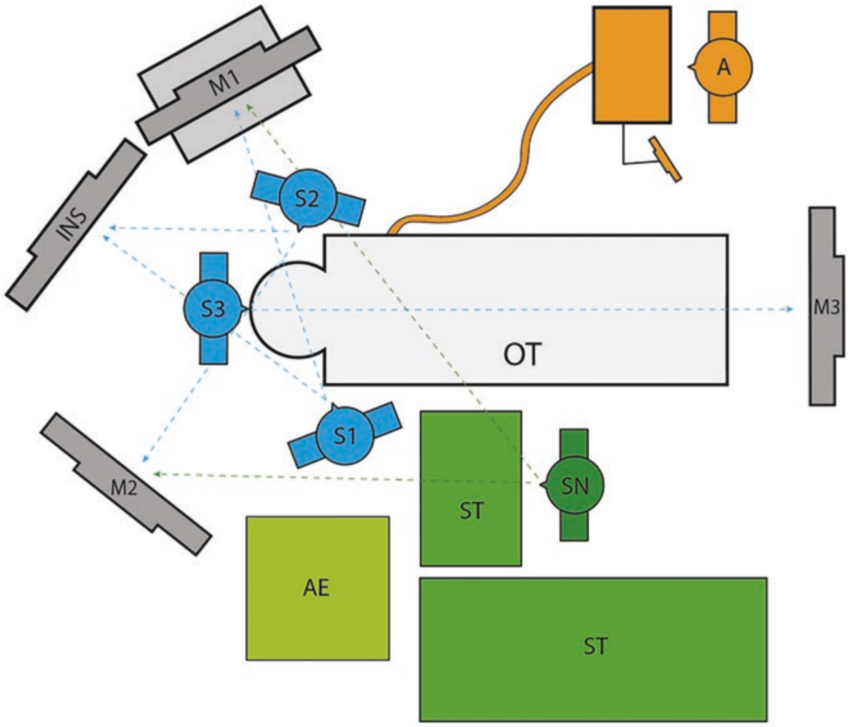


Fig. 11.1 Operating room-setting and instrumentation. Schematic representation of the location of surgeons, nurse, monitors, intraoperative navigation system, and other instrumentation during a standard transorbital procedure. Abbreviations: *A* anesthesiologist, *INS* intraoperative navigation system, *M* monitor, *AE* additional equipment (e.g. Ultrasonic Aspirator devices or Cryoprobes), *OT* operating table, *S* surgeon, *SN* scrub nurse, *ST* serving table; arrows: schematic representation of line of sight of surgeon and scrub nurse toward the monitors in the operating room

11.4 Superior Eyelid Approach

11.4.1 Indications

The Superior Eyelid Approach (SEA) is the real workhorse procedure among the Endoscopic Transpalpebral Approaches (ETA). It allows not only to manage orbital lesions but also to employ the orbit as a surgical corridor for selected skull base regions.

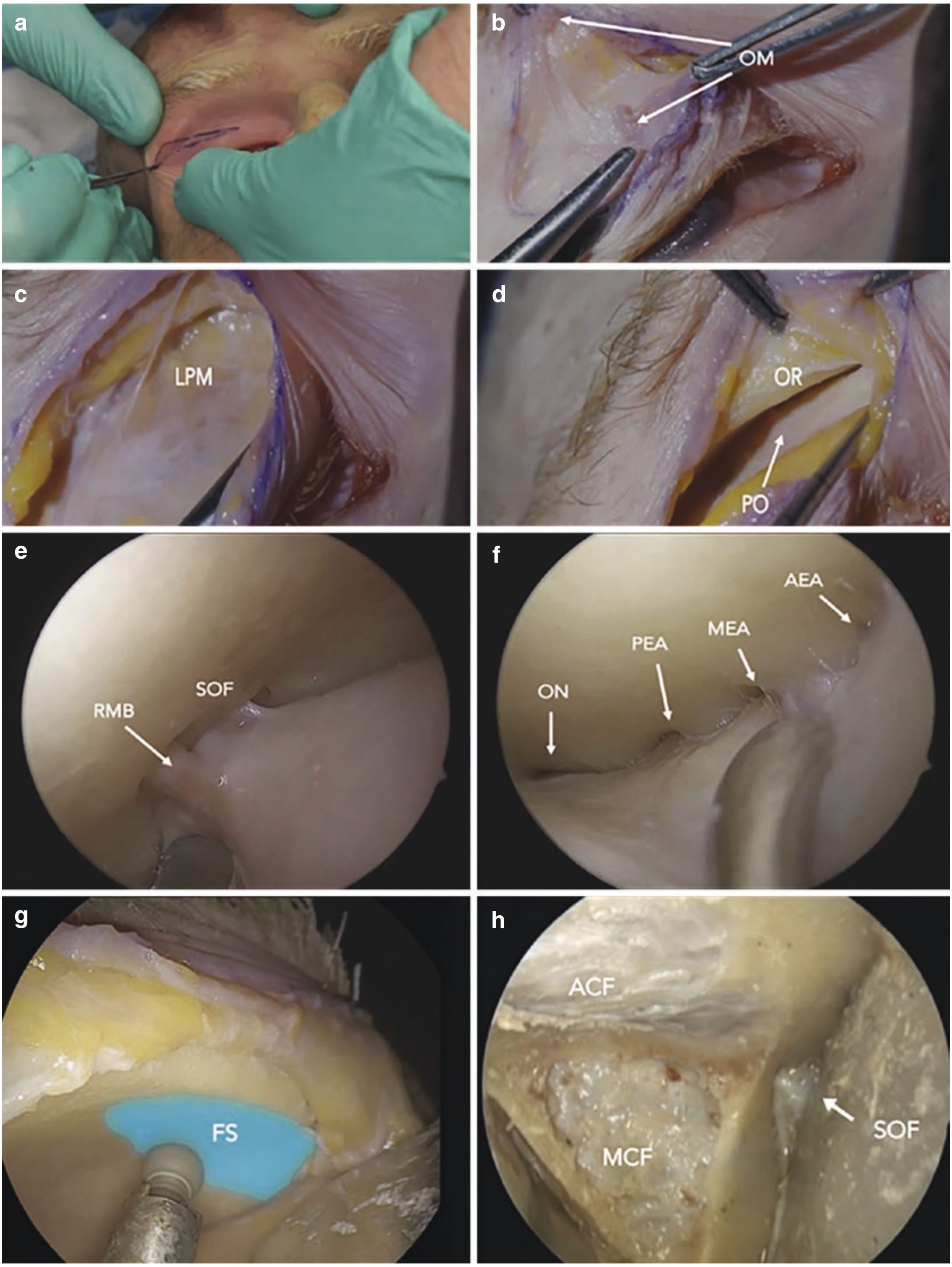
Considering the **orbit as a target**, the SEA can be adopted for lesions located laterally to the optic nerve, both in the extraconal and the intraconal space. This approach can be useful for biopsies, tumoral mass removal, drainage of intraorbital abscesses, and for treating superolateral orbital frame fractures [5] . In this setting, the SEA should be considered as a safe minimally invasive approach, alternative to more invasive traditional external procedures, often requiring osteotomies [16].

Considering the **orbit as a corridor**, the SEA represents a highway to reach the far lateral portion of the Frontal Sinus (FS), the Anterior Cranial Fossa (ACF), and the Middle Cranial Fossa (MCF). According to the pneumatization of the Frontal Sinus above the orbital cavity and the location of the disease within it (e.g., inflammatory pathologies, mucoceles, pedicle of benign lesions), traditional endoscopic endonasal approaches are sometimes unable to reach the far lateral portion of the FS itself [17, 18]. Novel techniques have been described, combined with Draf type II and III approaches in order to lateralize the fulcrum of the optics and instrumentation, thus overcoming the limit represented by the supero-medial orbital angle [19, 20] . Nonetheless, in a highly pneumatized FS, the orbit represents a valuable corridor to reach the lateral portion of the sinus, and in these cases the superior eyelid is the most employed approach. If a transdural approach is planned, the SEA may be indicated to manage lesions localized laterally to the most lateral limit of the Endoscopic Endonasal Approach (EEA) to skull base, namely, the lateral portion of the Superior Orbital Fissure (SOF), the retro-orbital region of the great wing of sphenoid bone, and the lateral wall of cavernous sinus [21] . In our clinical practice, we have gathered a significant experience with endoscope-assisted SEA, dealing with Spheno-Orbital Meningiomas [22]. Those tumors arise around the sphenoid ridge and present with a "carpet-like" growth pattern, usually invading the orbital region with their hyperostotic component. Presenting symptoms include unilateral exophthalmos, vision or visual field deficits, extraocular movement palsy, as well as cosmetic deformities. Transorbital approaches can be used in a very effective way to treat the symptoms caused by these neoplasms, instead of the traditional craniotomies (i.e., fronto-temporal, fronto-temporo-orbital, and supraorbital) [23, 24] . Other indications of SEA include the repair of skull base defects, the treatment of anterior and middle cranial fossa fractures, the drainage of epidural abscess or hematoma. Many cadaveric studies have demonstrated indeed the feasibility of an endoscopic amygdalohippocampectomy via a transorbital SEA [25]. If combined with an EEA or with other cranial techniques, the SEA gives rise to a multiportal procedure that overcomes the boundaries of a single approach [26].

11.4.2 Operative Technique

The skin incision for SEA (Fig. 11.2) is made within a hidden fold of the upper eyelid, which accounts for a nearly invisible postoperative scar. Dissection proceeds with sectioning the orbicularis oculi muscle, which is recognized due to the horizontal orientation of its fibers. Utmost care must be paid not to incise the levator palpebrae muscle, which is seen traversing the surgical field with vertically oriented fibers. In order not to damage this muscle, thus causing postoperative ptosis, dissection should be performed delicately in a superficial suborbicularis plane with a supero-lateral direction, until the orbital frame is reached. The decision to spare or to open the orbital septum depends on the purpose of the surgery. In any case, its opening will cause orbital fat herniation into the operating field, which must be managed through the use of retractors [2, 10]. After reaching the orbital rim, the periosteum is incised, and the surgical field enlarged in the same plane to grant a comfortable access for the optics and all the instrumentation needed. Subcutaneous stitches with silicone tubes might

Fig. 11.2 Overview of the superior eyelid approach. The skin incision is made within a hidden fold of the upper eyelid (**a**). Sectioning the orbicularis oculi muscle (**b**). Exposition of the levator palpebrae muscle, recognizable by the vertical orientation of its fibers (**c**). The dissection proceeds in the suborbicular plane, taking care to not damage the levator palpebrae muscle, until the orbital rim is exposed (**d**). 0^{o} endoscopic view of the orbital cavity during subperiosteal dissection, with exposure of the recurrent meningeal branch and the superior orbital fissure (**e**). The critical landmarks in this phase are the optic nerve, the posterior, middle, and the anterior ethmoidal arteries (**f**). Drilling of the orbital roof to enter the frontal sinus (**g**), which is identified with the use of intraoperative image-guidance system (light blue area). Exposure of the anterior cranial fossa and middle cranial fossa dura (**h**). Abbreviations: *OM* orbicularis muscle, *LPM* levator palpebrae muscle, *OR* orbital rim, *PO* periorbit, *RMB* recurrent meningeal branch, *SOF* superior orbital fissure, *ON* optic nerve, *PEA* posterior ethmoidal artery, *MEA* middle ethmoidal artery, *AEA* anterior ethmoidal artery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be helpful to enlarge the skin incision providing more space while reducing the risk of damaging the eyelid [4]. Once sufficient space is available, a 0° endoscope (Karl Storz, Tuttlingen, Germany) is introduced in the surgical cavity and the whole surgery is performed entirely under endoscopic vision. A subperiosteal dissection is advanced in order to visualize the intraorbital anatomical landmarks. The first one to come into view is the Recurrent Meningeal Artery (RMA), which represents an anastomosis between the middle meningeal and the lacrimal artery.

It is seen in most of the cases (about 60–80% of the population) traversing a separate bony canal in the supero-lateral orbital wall, the Hyrtl or meningo-orbital foramen, while in a minority of patients, it is the most supero-laterally located vessel in the SOF. Advancing from above downward and in a latero-medial direction, the SOF is visualized, while the Inferior Orbital Fissure (IOF) is reached extending the dissection infero-laterally. Proceeding from lateral to medial along the roof of the orbital cavity, the Optic Nerve (ON), the Posterior (PEA), and the Anterior Ethmoidal Arteries (AEA) are visualized. Until the identification of the intraorbital landmarks is completed, the surgeon must pay attention to preserve the periorbit, thus avoiding the herniation of the periorbital fat in the surgical fields, which significantly complicates intraorbital dissection.

Orbit as Target. The orbital content is entered with an incision of the periorbit at the approximate depth of the lesion, according to an accurate preoperative evaluation and often with the aid of the image-guidance technologies. The periorbital incision reveals the extraconal fat, which is more represented in the anterior portion of the retrobulbar region, while it is more scarce proceeding toward the orbital apex. After a dissection phase in the periorbital fat, the Lateral Rectus Muscle (LRM) represents the first anatomical landmark during transorbital procedures for lesions located laterally to the ON. Above the LRM, the lacrimal neurovascular "bundle," formed by the nerve, artery and vein, is found, overlying the superior surface of the LRM before its insertion. The RMA can enter the orbit at this level, usually joining the lacrimal artery. It can be spared or coagulated, according to the need. Near to the superior orbital fissure, posteriorly, the superior branch of the oculomotor cranial nerve is visible. Moreover, the superior ophthalmic vein can be identified more posteriorly, right above the optic nerve and below the superior rectus muscle. Posteriorly, toward the apex and the SOF, the inferior division of the third cranial nerve can be seen. To notice, all these anatomical structures are not always encountered intraoperatively. In fact, once the lesion is identified, surgery proceeds with a gentle pericapsular dissection, with the use of blunt instruments and cottonoid pledges, which are used to isolate the lesion from the surrounding anatomical structures. Once a portion of the lesion is exposed, in case of well circumscribed and encapsulated lesions, such as for example orbital venous malformation type I (OVM, ex cavernous hemangioma), the use of cryoprobes has proven useful to grasp the lesion without the need to further proceed in the dissection in the intraconal space, as dissection can be completed outside the orbital content once the lesion is properly retracted, similarly to medially located intraconal lesions removed via a transnasal route. After removal of the lesion, accurate hemostasis is performed, with the cautious use of bipolar, irrigation with warm saline, and eventually hemostatic agents. In most of the cases, no reconstruction is needed after intraorbital surgery. In case of removal of bulky lesion, the considerable empty space might be filled with autologous fat to reduce the risk of post-operative enophthalmos, but this is rarely needed [23]. Figure 11.3 illustrates a clinical case example of SEA to the orbit for removal of an OVM type I.

Orbit as Corridor. The surgical steps when the orbit is not intended as the target, but the corridor of the approach, are the same as the ones listed in the previous paragraph, up to the visualization of the intraorbital landmarks. Again, it is important to underline that to further proceed with intracranial surgery, dissection is to be performed without accidentally opening the periorbit. During this phase, moments of retraction of the orbital content are realized with malleable retractors and a soft Silastic sheet (Dow Corning, Midland, Michigan, USA) protecting the periorbit.

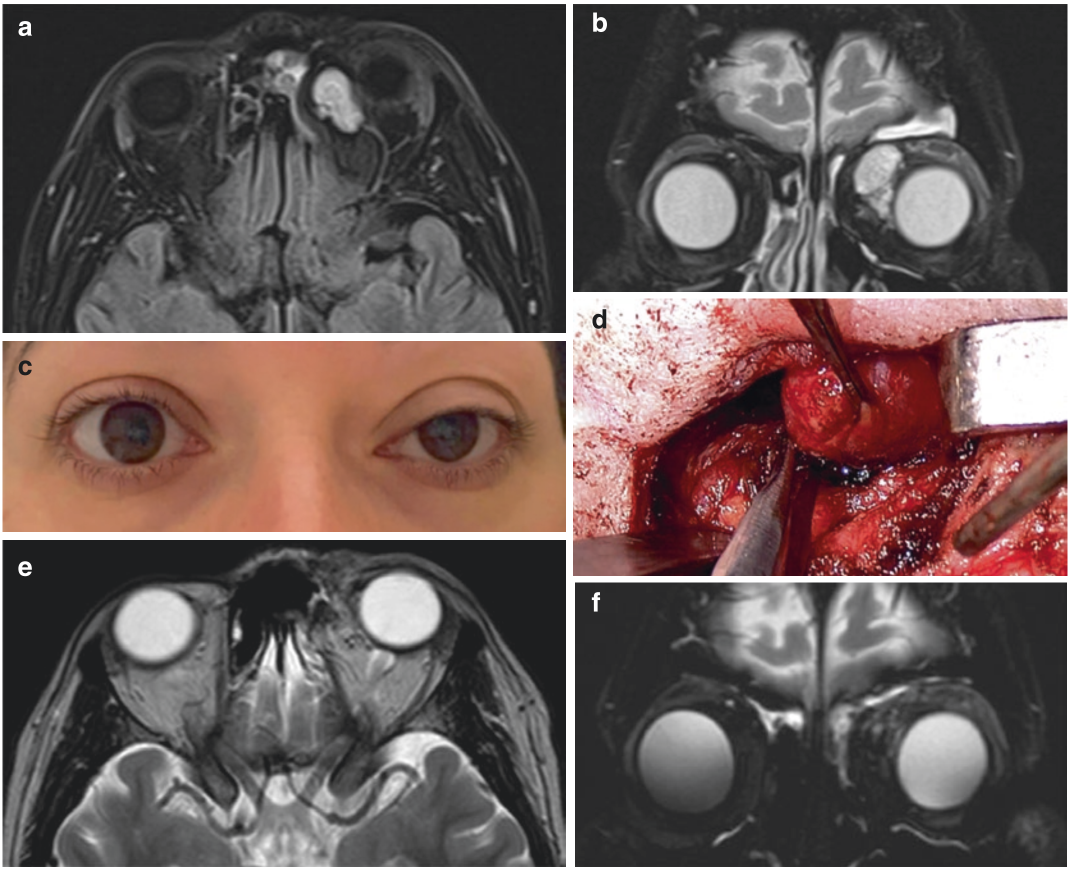

Fig. 11.3 SEA for removal of OVM type I (e.g., cavernous hemangioma). Illustration of a 37-year-old female patient who presented to our department complaining of left periorbital swelling, proptosis, and ocular pain. MRI with contrast was performed, showing a left anterior extraconal supero-medial orbital cavernous neoformation, suspected for OVM type 1, complicated with an ipsilateral frontal mucocele. Preoperative MRI in axial Flair sequence (**a**), coronal T2-weighed (**b**). Periorbital swelling and proptosis (**c**). The patient underwent removal of the neoformation via a SEA (**d**). Postoperative axial (**e**), and coronal T2-weighed MRI (**f**), which demonstrated the complete resection of the orbital hemangioma

For a transorbital access to the frontal sinus, a proper anatomical landmark to safely enter the sinus has not been yet identified. The FS might be variable in pneumatization and is localized very anteriorly along the orbital roof. In most of the cases, the floor has already been interested by the pathology (e.g., orbital complication of frontal sinusitis with orbital wall erosion), so that the sinus can be entered through the pre-existing defect. On the contrary, in case of an intact orbital roof, the intraoperative image-guidance systems are helpful to properly plan the osteotomy [27]. Once entered the sinus, the target of the surgery is usually easily visualized and managed, with the use of either straight or curved instrumentation [28]. The combination of the SEA with an expanded approach to the frontal sinus is usually able to manage the sinus in its entirety [29] (Fig. 11.4).

For an anterior cranial fossa approach, a craniectomy with a diamond-burr is performed by drilling the orbital roof (in the laterobasal frontal bone) and part of the lesser wing of the sphenoid bone. The greater wing is left intact in case of a

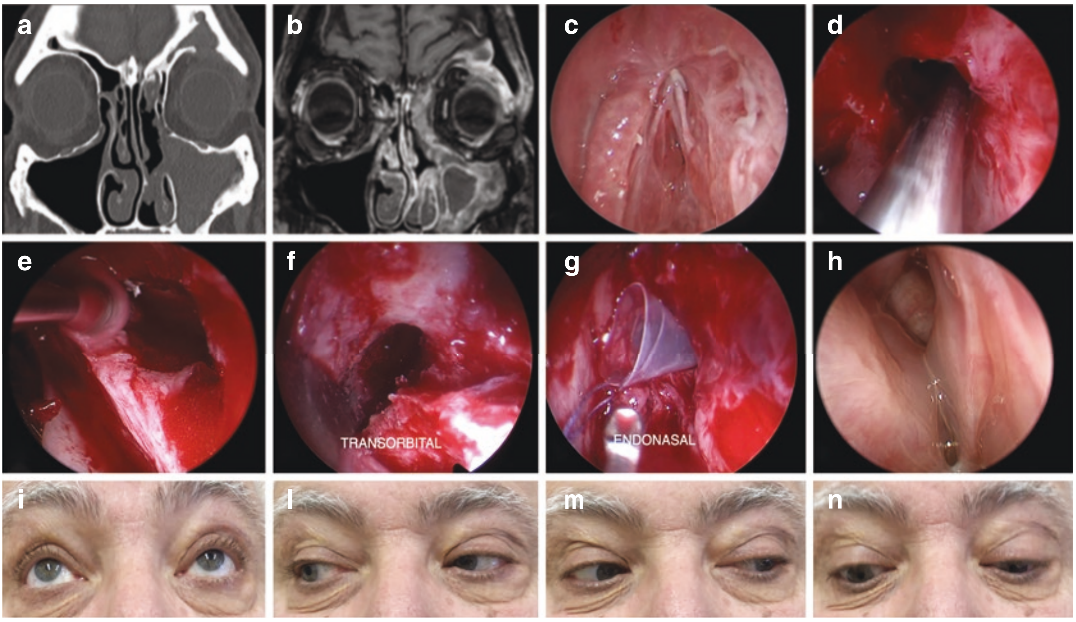

Fig. 11.4 Combined endonasal-transorbital approach for a fronto-orbital abscess. Case illustration of a 76-year-old male who underwent a previous Draf IIA procedure for a left fronto-ethmoidal empyema from Staphylococcus Aureus. After 3 months, he complained of periorbital swelling and tenderness. Coronal CT scan (**a**) and T1-weighed MRI with contrast (**b**), demonstrated a left fronto-ethomoido-maxillary sinusitis with erosion of the orbital roof. He underwent revision surgery by means of a combined endoscopic endonasal and transorbital approach, due to the far lateral location of the inflammatory process within the frontal sinus. Stenosis of left frontal sinusotomy can be seen (**c**). The re-opening is demonstrated under endoscopic view (**d**). Moreover, the frontal ostium was enlarged through drilling via the transorbital approach (**e**, **f**). At the end, a frontal stent was positioned, as seen from the endonasal perspective (**g**). 1-month postoperative endonasal control that demonstrated the patency of left frontal sinus (**h**). The regular eye motility was assessed 1 year after surgery (**i**-**n**)

pure transorbital exposure of the anterior skull base. The boundary of this surgical approach can be summarized as follows: orbital rim superiorly, lesser sphenoid wing inferiorly, pterional region laterally, lateral aspect of the SOF medially. After the craniectomy, the dural layer of the frontal supraorbital region is unveiled. Dura is divided according to the specific target, and the basal frontal lobe along with the orbital gyri are exposed.

For a transorbital middle cranial fossa approach, the SOF and the IOF have to be fully exposed, as well as the greater wing of the sphenoid until the superolateral orbital wall. The craniectomy is carried on within the greater sphenoid wing, limited supero-medially by the superior orbital fissure and laterally by the temporal muscle (Fig. 11.2). The boundary of this surgical approach can be summarized as follows: SOF superiorly, IOF infero-medially, periosteal layer of the temporalis muscle laterally, and the floor of the middle cranial fossa inferiorly [2, 5]. If more space is needed for the resection, the craniectomy can be enlarged inferiorly to include the floor of the middle cranial fossa and superiorly by removing part of the lesser wing of the sphenoid bone [26]. If an intradural approach is anticipated, the temporal dura is opened, and the polar region of the temporal lobe is reached.

In case of intradural pathology, our experience proves that dural reconstructions is often not needed, because the orbital structures behave like a natural sealant, even if the theoretical risk of Cerebrospinal Fluid Leakage (CSF-L) exists [2, 5]. Nevertheless, several skull base closure techniques have been described in the literature, even for transorbital approaches. Some authors have considered the possibility to perform a multilayer reconstruction, in line with those performed in transnasal endoscopic craniectomy. Alqahtani et al. described a multilayer technique in which they put an intradural layer with synthetic graft, followed by muco-periosteal septal graft overlay covering the superior orbital wall defect [30]. Other possibilities include the use of autologous materials, such as iliotibial tract and fat tissue harvested from patient's thigh [26]. The orbital content dislocated during the intervention is repositioned in its original location. At the end, the wound is closed in layers, and the skin of the upper eyelid is sutured with a running locked intradermal suture (6–0 Fast-Absorbing Surgical Gut Suture). This kind of closure provides excellent functional and cosmetic outcomes since the scar is nearly invisible in the long postoperative period.

11.4.3 Complications

In terms of skin incisions and bone work, the SEA represents a minimally invasive approach. However, surgical site infections, postoperative edema, and diastasis of the cutaneous suture still represent minor concerns that need to be mentioned, even if they are no longer frequently found in clinical practice, as long as strict asepsis is observed.

From a functional standpoint, the SEA involves the risk of damaging the LPM during the phase of subcutaneous dissection in the suborbicularis plane. This complication is extremely uncommon to occur provided that proper training in performing the access is provided. It should nonetheless be openly discussed with every patient before surgery as postoperative ptosis is a significant complication regarding both function and aesthetics.

The risk of ischemic damage to the optic nerve and other intraorbital structure due to compression of the orbital content has already been mentioned. To avoid this, the surgeon should provide moments of relaxation of the orbital content during the surgical procedure [2, 5]. As long as this technical tip is respected, the safety of this type of surgery has been demonstrated by numerous cases, and in the personal experience of the senior authors (P.C. and D.L.), neither intraorbital nor transorbital procedures have been associated with any occurrences of postoperative visual deficit due to ischemic or traumatic damage.

To perform this type of surgery, one must have a thorough understanding of anatomy and exceptional endoscopic abilities, as the majority of potential hazards result from inappropriate maneuvers conducted during the dissection in the intraorbital compartment, which is performed after opening the periorbit. The same can be said about the surgery's intracranial and skull base phases. To prevent damage to critical neurovascular structures, one must have a thorough understanding of the surgical anatomy of the skull base, intracranial, and intraorbital spaces as seen from this novel perspective provided from the SEA.

The danger of postoperative CSF-L can be a concern only during extensive surgeries with resulting large skull base defects, which are not frequently performed via such minimally invasive techniques. These large gaps can be repaired using a variety of procedures (see above), but in the senior authors' personal experience, in the majority of times postoperative CSF-L can be prevented by simply repositioning the orbital content, which acts like an effective sealant for the skull base defect.

In the immediate postoperative period, bleeding represents the most daunting complication to be aware of. The disruption of smaller blood vessels contained in the orbital space might cause a retrobulbar hemorrhage, with collection of blood that can result in the compression of the optic nerve, with consequent optic neuropathy possibly leading to amaurosis or even irreversible vision loss. Indirect signs of increased intraorbital pressures are proptosis (bulging of the globe), increased orbital tension, orbital pain, reduced ocular motility and a change in shape and size of the pupil, with fixed and dilated pupil not responding to light reflex as sign of irreversible damage to the optic nerve and or ciliary ganglion [31], configuring the so-called orbital compartment syndrome. This is more likely to occur during transorbital approaches, because during endoscopic transnasal surgery, the blood drains into the nose. Thorough preoperative assessment, an accurate intraoperative hemostasis, and a regular monitoring of blood pressure are essential measures that should be considered by the surgeon to avoid this complication. This complication can be observed immediately after surgery, it is advisable to return to the operating room to perform orbital decompression. If the complication is observed in the department in a woke patient in the first or second postoperative day, without the possibility for immediate return to the operating room, prompt orbital decompression via lateral canthotomy and inferior cantholysis is an effective maneuver that can be carried out in a local anesthesia setting [32, 33].

11.5 Inferior Eyelid Approach

Inferior Eyelid Approach (IEA) is a surgical route adopted less frequently, compared to the SEA, because orbital lesions rarely occur in the lower quadrants [16], and most of them can be managed with an exclusive endoscopic transnasal approach since the epicenter of the lesion lies inferior to the so-called plane of resectability (POR), which is a plane extending from the contralateral nares through the long axis of the optic nerve [34]. Nonetheless, the IEA can be adopted to manage extraconal and/or intraconal inferiorly located lesions, to achieve an inferior orbital decompression and, most frequently, to repair orbital floor fractures. With transorbital intent, this approach allows the exposure of the floor of the middle cranial fossa as well as to reach the infratemporal fossa, where the main targets are represented by the extracranial segments of the maxillary and mandibular nerves [2].

As far as the technique is concerned, a subtarsal incision located about 3–5 mm below the free edge of the lower eyelid is carried out [5]. The dissection is performed in the plane below the orbicularis muscle and a skin-muscle flap is elevated. Thereafter, the following exposure is accomplished in the pre-septal plane until the orbital frame is reached and the periosteum is clearly visualized. The latter can be incised, so that the dissection continues along a subperiosteal plane, up to the IOF, in order to obtain adequate surgical space for the subsequent operative phases. During the detachment, any venous bridging veins running between the orbital cone and the bone can be coagulated and cut. If the aim of the procedure is to access the orbital structures, the orbital septum is opened and the intraorbital phase of the surgery is carried out with the same principles already exposed in the previous paragraphs. The IEA also allows for a transorbital route to the floor middle cranial fossa. This is possible with the transection of the content of the inferior orbital fissure with an anterolateral to posteromedial direction, to expose the orbital floor and the anterior maxilla as far as the orbital apex [2]. Most encountered complications are related to the suboptimal aesthetic results related to the skin incision and paresthesia of the region of the infraorbital nerve in case of section of the IOF content.

11.6 Medial Conjunctival Approaches

Medial conjunctival approaches comprise a set of surgical techniques employed to address pathologies located in the medial and anterior region of the orbit, via an incision of the conjunctiva of the medial canthal region [35, 36]. They include the precaruncular, transcaruncular, and retrocaruncular approaches, which differ for the site of the incision and the initial phases of dissection. They all address the same anatomical area and, compared to earlier procedures that target the medial orbital region, such as the cutaneous (i.e., Lynch incision), trans-eyelid, trans-fornix, or medial rectus plane approaches, they expose the anatomy in a novel way [37].

When considering transorbital endoscopic procedures to the skull base and the orbit, in the authors' experience, these approaches are used less frequently than the SEA. They find the main indications in the management of medial intraorbital lesions with the epicenter located anteriorly to a coronal plane passing through the mid-orbit. This anatomical region is the least accessible for the SEA, due to its location medial to the sagittal plane passing through the optic nerve, and for the endoscopic transnasal approach, as dealing with anterior lesions can be challenging using the nasal corridor. The technique is also described for orbital fracture repair, and anatomical reports confirm the adequacy of the approach to expose the anterior ethmoidal artery [38, 39]. In case of failure with transnasal endoscopic ligation of the artery, the medial conjunctival approaches potentially allow to manage severe nasal bleeding through the transorbital route, avoiding cosmetic deformities or visible scarring that can occur as a result of a cutaneous approach (i.e., Lynch incision) [40]. To note, the contralateral precaruncular approach was also used to address lesions and defects located in the lateral aspect of well-pneumatized sphenoid sinuses, in a multiportal fashion combined with a transnasal endoscopic approach [41].

As far as technique is concerned, a vertical incision is made at the level of the caruncle and is extended 10 mm superiorly and inferiorly in the conjunctiva to create the surgical corridor. To perform the transcaruncular approach, the incision is made directly through the caruncular tissue and dissection is then carried out in a preseptal plane toward the posterior lacrimal crest; the precaruncular approach uses the same preseptal plane, but the incision is performed anteriorly and medially to the caruncular tissue, whilst for the retrocaruncular approach, the incision is made between the caruncle and the plica semilunaris and dissection is extended to the posterior lacrimal crest in a retro-septal plane [42]. The medial orbital wall is reached 1–2 mm posteriorly to the posterior lacrimal crest, where the periosteum is incised. During this phase of the surgery, the Horner muscle represents the main surgical landmark and is kept anteriorly. Attention must be paid to avoid herniation of the orbital fat in the surgical field to avoid getting disorientated and, inevitably, prolonging the duration of the procedure. After the periosteum is incised, the dissection proceeds in a subperiosteal plane, avoiding fracturing the lamina papyracea medially while proceeding more posteriorly into the orbit. Surgical access is improved by combining the medial incision with an inferior fornix incision. The medial and anterior portions of the orbital walls are easily exposed with this approach, so that fractures herein located can be managed with these techniques. In case of intraorbital lesions, after exposure of the surgical landmarks, the periorbit can be incised and intraorbital dissection proceeds with the same principles in the previous paragraphs. With these approaches, considering the anterior location of both the surgical corridor and the target, the dissection can be performed either under direct vision or with the aid of magnification devices (e.g., microscopes, exoscope, surgical loupes, or endoscope in case of more posteriorly located lesions). At the end of the procedure, the conjunctiva and caruncle are closed with interrupted 6–0 fast-absorbing gut sutures [37]. The most reported complications include damage to the lacrimal pathway, to the lamina papyracea and, potentially, to the skull base, with resulting CSFL. Minor ones include surgical site infections and, rarely, unpleasant aesthetic results. The precaruncular route puts the lacrimal system in a relatively higher jeopardy; the retrocaruncular one implies a slightly higher risk of injuring the periorbit before reaching the target, while the transcaruncular incision might cause increased risk of postoperative edema and erythema due to the complex histology of the caruncula itself [42]. However, a careful dissection is able to provide adequate access without major risk of complications in most of the cases [40].

11.7 Limits of Endoscopic Transorbital Approaches

11.7.1 Anatomical Limitations

Lesions that are located infero-medially to the optic nerve are the main contraindications to using the transpalpebral corridor. The transnasal route is the gold standard method in these clinical scenarios (see above). Almost all other locations can successfully be managed using transpalpebral corridors, SEA for superiorly positioned lesions and IEA for inferiorly located lesions. Although large dimensions and the apical location of the lesions represent actual concerns for endoscopic transorbital approaches, no specific study has been carried out that explicitly states the characteristics of the lesion that demand for an open orbitotomic approach. On the one hand, radical resection is often not required at all cost and, on the other, it is always possible to revert the approach to an open orbitotomic or craniotomic one, for example, in case of intraoperative finding of intractable adhesions. Lesions that are posteriorly expanded toward the squamous section of the temporal bone or laterally toward the temporal fossa are absolute contraindications to endoscopic transpalpebral approaches to the anterior and middle cranial fossa. A fronto-temporal or pterional craniotomy may be the most effective surgical procedure in these circumstances.

11.7.2 Endoscopic Technical Limitations

Endoscopic surgery has several drawbacks that cannot be neglected, even considering the possibility of magnification and the potential to operate successfully in small anatomical spaces. First of all, it offers bidimensional vision in an unfamiliar anatomical region, which can occasionally lead to disorientation. Second, maintaining clear eyesight is essential for the surgical intervention to be successful, despite the working space's limited width, the possibility of fat herniation, and any bleeding that may occur. Finally, in order to avoid instrumentation conflicts or poor-quality vision, it is imperative to develop a synergistic working habit between the two or three surgeons who are operating simultaneously in the orbital cavity. Some of these limitations might be overcome with the use of technological advancements such as intraoperative lens irrigation devices, cryoprobes, and intraoperative image guidance systems. However, a steep learning curve is necessary, particularly adequate, and in-depth preclinical anatomical training. This is necessary to develop both manual skills and anatomical knowledge, which is the crucial factor preventing the surgeon from getting lost during this particular subset of endoscopic procedures.

11.8 Postoperative Workup and Follow-Up

The postoperative evaluation aims to recognize and treat any surgical complications and to evaluate any clinical issues that might develop immediately or long after the procedure. As for preoperative workup, postoperative care should be performed in a multidisciplinary setting with examinations performed by the whole orbital team (otolaryngologist, neurosurgeon, ophthalmologist, and dedicated radiologist).

During the immediate postoperative period, vision represents the main concern and is to be checked regularly. A universally accepted protocol for elective orbital surgery doesn't exist, but in personal experience, a periodic red saturation test performed every 2 h for 48 h, borrowed from the protocols of orbital trauma management. This appears like an acceptable compromise between what patients can do and the knowledge that irreversible vision loss may be occurring with vascular impairment lasting longer than 90 min. In this phase, controlling pain and nausea is crucial to reduce the likelihood of increased orbital venous pressure and the risk of intraorbital bleeding. However, attention is to be paid not to excessively mask pain, as the patients should be able to report the appearance of orbital pain and/or discomfort, which might represent the red flag for orbital edema or hemorrhage [43].

An early imaging control is usually scheduled during hospitalization. This is not applied in every single case but has become part of the clinical practice. In case of intracranial work after SEA for ACF or MCF lesions, a CT scan is performed in the first or second postoperative day and before discharge in order to monitor the postoperative pneumocephalus and the occurrence of possible intracranial complications (e.g., bleeding). For intraorbital procedures, if feasible, MRI performed in the first 72 h is the preferred imaging method, as it is a highly effective way to detect residual lesions with reduced risk of false-positive, as postoperative edema and scarring are still to develop in this early postoperative phase. Moreover, it provides a useful reference image for subsequent follow-up.

Finally, patients are submitted to adjuvant treatments or to a regular follow-up program. As a general rule, the first clinical examination is performed 10–15 days after the procedure, after the pathologic examination is completed. In this occasion, a multidisciplinary consultation is possible, and the patient is then addressed to a specific follow-up protocol according to the biology of the pathologic condition treated. A detailed examination is out of the aim of this chapter. As a rule, for traumatic or benign conditions, clinical and radiologic examinations are performed twice in the first year and then once every 1 or 2 years or according to the occurrence of symptoms. For malignancies, the follow-up is more strict and follows the principle of sinonasal malignancies surveillance [44, 45].

Two months after surgery, an ophthalmologic and orthoptic examination is performed to assess the patient's visual acuity and field once healing is completed. If any pathological finding is confirmed as outcome of the procedure, the patient is examined for possible correction and following examinations are performed according to ophthalmologic opinion. In case a visual deficit or motility impairment appears as new onset symptoms, imaging is promptly executed in order to rule out possible recurrence of the disease.

Clinical, ophthalmology, and radiologic examination during the surveillance should be recorded and stored in a dedicated database. This should be part of the practice for every kind of surgical intervention but is of utmost importance for orbital surgery considering the rarity of the diseases and the need to collect data in order to progressively improve outcomes.

11.9 Future Perspectives

A profound evolution of skull base surgery was observed in the last decades, with a progressive shift from the more classical extensive transcranial procedures toward minimally invasive approaches. In this setting, the advent of endoscopic techniques has represented a revolution for the management of orbital pathologies, thanks to the magnified view and the possibility to expose the lesion and perform dissection in such a narrow anatomical area, which is the orbital cavity. Neuroanatomical research, mainly intended as cadaver dissections preclinical studies, have played a pivotal role in the refinements of novel approaches "to and through" the orbit. Indications are constantly expanding, and currently include selected intraorbital, skull base, and even intra-axial lesions, both benign and malignant in nature [46]. In recent years, the development of dedicated medical software, 3D volumetrics evaluation, computer analysis, and machine learning are providing a further effort to the refinement of contemporary orbital surgical approaches. Many contributions demonstrate the importance of medical engineering to perform operations tailored according to the individual's anatomy [47–49].

Guizzardi et al., in a remarkable conceptual paper, reported four main steps for planning patient-tailored transorbital approaches. Starting from the study of bone normal anatomy on a dry skull (step 1), all the relevant orbital structures were exposed during the following cadaveric dissection (step 2). Soon after, authors performed a 3D quantitative and qualitative assessment of the post-dissection data, demonstrating the anatomic targets that can be reached via the endoscopic transorbital SEA. The evaluation of the exposure and the working angles with a volume of safe bone removal was crucial to calculate the working areas and the surgical freedom of the approach (step 3). Finally, the last step consisted in transferring the presurgical planning to the clinical practice (step 4) [50].

Among the possible innovations that could lead to an improvement of transorbital procedures, we can expect the introduction of new kinds of autostatic orbital retractors that could facilitate the divarication of the orbital contents, which sometimes still represents a hindrance during the dissection [51]. Moreover, new image-guidance systems could provide a real-time navigation of intraorbital structures avoiding the brain shift, and dedicated instruments might be capable of increasing the safety and the effectiveness of this type of procedure [46].

Finally, among the most fascinating innovations in orbital operations, we can't forget the robotic systems. In a recent publication, Jeannon et al. have introduced the term Robotic-assisted Orbital Surgery (RAOS). Authors claim that RAOS offers multiple advantages over the conventional techniques, such as high definition 3-dimensional optics, dexterous wristed instruments, motion scaling, and tremor filtration [52]. Wang et al. have reported their experience with robot-assisted orbital decompression in 18 patients affected by Graves' ophthalmopathy. The robot utilized was the da Vinci Xi surgical system (Intuitive Surgical, Inc., Sunnyvale, CA). According to their experience, it provided the stability, dexterity, and good visualization necessary for orbital fat decompression surgery [53].

11.10 Conclusions

For decades, transcranial or craniofacial approaches have represented the mainstay of surgical approaches to address the orbital region, even if burdened by a considerable invasiveness [3, 54].

More recently, a profound evolution in endoscopic approaches have reshaped the panorama of orbital surgery, proved their efficacy while granting a reduced morbidity of the procedure, along with more pleasant aesthetic results [10, 55, 56]. One should be aware that the concept of minimal invasiveness does not depend on the entry wound size, but on the limited impact of the procedure on the patient's quality of life. In this respect, transorbital endoscopic surgery should not be considered as an alternative technique for replacing the classical expanded endoscopic endonasal approaches or traditional external craniotomies, but should be considered as a valid alternative proposed as an additional corridor able to improve visualization while minimizing surgical demolition and maximizing the instruments' maneuverability. As already emphasized, the orbital team should be able to convert to external approaches whenever needed (e.g., inadequate surgical exposure, excessive bleeding, intraoperative complication, or unexpected intraoperative findings).

This chapter was intended to be an introductory lecture to familiarize with a niche of surgical approaches to the orbital region and confining anatomical areas. These approaches require a sound anatomical knowledge, a steep learning curve and, more importantly, a multidisciplinary experienced team, not only during the surgical act but from the time of the diagnosis to the post-operative surveillance.

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