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REVIEW ARTICLE - TUMOR - MENINGIOMA

Surgical management of Tuberculum sellae Meningiomas: Myths, facts, and controversies

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Abstract

Background The optimal management of tuberculum sellae (TS) meningiomas, especially the surgical strategy, continues to be debated along with several controversies that persist.

Methods A task force was created by the EANS skull base section committee along with its members and other renowned experts in the field to generate recommendations for the surgical management of these tumors on a European perspective. To achieve this, the task force also reviewed in detail the literature in this field and had formal discussions within the group.

Results The constituted task force dealt with the practice patterns that exist with respect to pre-operative radiological investigations, ophthalmological and endocrinological assessments, optimal surgical strategies, and follow-up management.

Conclusion This article represents the consensually derived opinion of the task force with respect to the surgical treatment of tuberculum sellae meningiomas. Areas of uncertainty where further clinical research is required were identified.

Keywords Tuberculum sellae meningiomas · Surgical technique · Skull base · Craniotomy · Visual outcome · Suprasellar · Extended endoscopic transsphenoidal approach · Pituitary function · Minimally invasive neurosurgery

Introduction

Tuberculum sellae (TS) meningiomas accounts from 5–10% of all intracranial meningiomas and typically arise from the dura mater of tuberculum sellae, chiasmatic sulcus, and limbus sphenoidale [1] [2–5]. Visual disturbance is the most common clinical presentation, up to 80% according to the series of Schick et al. [6], because of the intimate anatomical relation between tuberculum sellae and the optic apparatus. TS meningiomas in fact displaces the optic apparatus, and frequently up to 67% invades [7], the optic canals leading to a decrease of visual acuity and visual field deficit [8]. The visual deficits are often asymmetric, reflecting the off-midline origin and then the pattern of optic nerve and chiasmal compression,

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according to recent published literature [2]. Other less common symptoms and signs are represented by headache, dizziness, seizures, endocrine disturbance, altered behavior, and cranial nerve deficits [2, 9–11].

TS meningiomas have been traditionally considered as part of the group of "suprasellar meningiomas" which also include meningiomas originating from the dura of planum sphenoidale, diaphragma sellae, and anterior clinoid process [12]. This nomenclature has generated some difficulties in the interpretation of surgical series which often include heterogeneous entities. The "true" TS meningiomas usually tend to elevate the optic apparatus while planum sphenoidale meningiomas push the optic apparatus down and backwards [13]. This difference is quite significant because in case of true TS meningiomas, one should dissect the vessels (coming from superior hypophyseal arteries) supplying the inferior aspect of the apparatus, while in planum sphenoidale meningiomas that do not extend posteriorly, this dissection of the vessels is minimal. This heterogeneity could partially explain the different results found in the literature especially concerning the visual outcome [14]. Furthermore, TS and diaphragma sellae (DS) meningiomas are often grouped together as TS meningiomas, although they have different sites of origin [15, 16] and display a different behavior. [15, 17, 18]

The optimal management of TS meningiomas, especially the surgical strategy, continues to be debated. The EANS skull base section was created in October 2017, and its board decided to review the state of the art with respect to some controversial topics in the field, in order to generate recommendations on a European perspective. This article deals with surgical treatment of tuberculum sellae meningiomas and it represents the consensually derived opinion of the EANS skull base section board with the valuable participation of invited renowned European experts in this field after extensive review of the literature and formal discussions within the group. This work gathers recommendations from our specific working group to serve as basis for young neurosurgeons and to stimulate discussions and debates with other European and international experts in the field.

Radiological assessment

The literature supports the use of a complete preoperative neuro-radiological examination including MRI and CT scan. A contrast-enhanced MRI is performed in order to study tumor relationship with surrounding anatomical structures, dural tail, optic canal invasion, eventual vascular encasement, and pituitary stalk position [12, 19]. Makarenko and colleagues [20] also underlined the role of FIESTA (fast imaging with steady state acquisition) sequences in order to properly study the relationship between the tumor and the cranial nerves. Hayashi et al. [21], also, furthermore recently showed the possibility of predicting a firm adhesion (thus complicating surgery) between the tumor and the optic nerve by using the FIESTA sequence.

Preoperative computed tomography may add useful information about hyperostotic bone at the site of origin of the tumor, anatomy of the sinuses, and also about intratumoral calcifications [22], [19, 23], [6, 9, 24]. A computed tomography angiography could be performed to better assess the relation with vascular structures [2]. A few authors still perform a conventional cerebral angiography before surgery [2, 19] even if the same information could today be obtained with an MRI thereby avoiding the risk of an invasive procedure. The majority of authors perform the first post-operative MRI 3 months after surgery and then yearly for the initial follow-up of WHO grade I meningiomas [11, 25, 26].

The literature supports the use of a complete preoperative neuro-radiological examination including MRI and CT scan. DSA may be considered obsolete in current practice. The first post-operative MRI should be performed within 3 months. In case of gross total resection (GTR), the MRI could be performed on a yearly basis. Modifications to this could be introduced in particular situations depending on the histopathological data, possible indications for radiosurgery (in cases of incomplete resection), and presence of surgical complications.

Neuro-opthalmological evaluation

The large majority (60–90%) of patients in these series were presented with visual acuity and visual field impairment at diagnosis [23] [27] [28, 29]. The preoperative and postoperative visual acuity is usually assessed by using the Snellen chart and the visual fields by using the standard Goldmann perimetry techniques [7, 23, 30, 31]. The majority of authors [7, 11, 13, 14, 31–35] have used the VIS (visual impairment score) (guidelines of the German Ophthalmological Society) that combine the assessments of visual acuity and visual fields. This scoring system, firstly applied by Fahlbusch et al. [17] for TB meningiomas, is determined by adding the scores in the specific tables that evaluate the visual acuity and visual field defects. The score ranges from 0 to 100 with lower VIS score that reflects better visual function. VIS is a simple and largely diffused system that allows a precise comparison of the outcome between the different surgical series. The first post-operative examination is generally performed within 1 month [2] and repeated if necessary.

Considering the high probability of visual impairment, the literature supports the use of a detailed neuro-ophthalmological examination including visual acuity, visual field examination, optic fundoscopy, optical coherence tomography (OCT) and examination of oculomotor function, before and usually 3 months after surgery (or earlier if there are new deficits). The use of an objective scoring system, such as the VIS, should be encouraged to allow comparison between the surgical series.

Endocrinological assessment

The reported rate of preoperative endocrinological disturbances remains variable in the literature (up to 42% of the patients). It needs to be considered that the different modalities employed to assess the pituitary function was variable across the series and many series had incomplete data [9, 36]. Most of the series however reported a low rate of anterior pituitary dysfunction ranging from 2 to 8% [9, 16]. According to a meta-analysis focused on anterior midline skull base meningiomas, endocrine abnormalities were preoperatively detected in 8.4% of the patients [37]. The incidence of new post-operative impairment of anterior pituitary function is very low in the majority of surgical series [17, 26, 29, 36].

Post-operative diabetes insipidus, usually transient, has been reported in 3–26% of the patients [36], but there are some authors who did not observe any case of posterior pituitary-hypothalamic impairment [17, 26]. Post-operative hyponatremia, accounting for the 25.8% of patients in the surgical series of Fujio et al. [36], is rarely reported [38] and is usually caused by the syndrome of inappropriate antidiuretic hormone secretion, hypocortisolemia, excessive fluid intake, over administration of desmopressin, and hypothyroidism. Fujio et al. [36] describe the use of a protocol of steroid coverage which was discontinued 2 days after surgery with the first evaluation for chronic cortisol replacement 5–7 days after surgery.

The literature supports the use of a complete endocrinological assessment before surgery and then a post-operative assessment 1 week and 3 months after surgery. This includes the monitoring of fluid intake and urinary output and to measure urine-specific gravity daily for 4–5 days in the post-operative phase to detect any abnormalities of posterior pituitary-hypothalamic axis. Especially when steroid coverage is not done in the peri-operative period, attention needs to be given to the development of hypocortisolism and/or other endocrinological disturbances.

Surgical classification

The first classification for these tumors was created by Cushing and Eisenhardt in 1938 who proposed a four-stage classification according to size [39]. They focused on clinical presentation and coined the term "chiasmal syndrome" which was not, however, appropriate to characterize the anatomical origin of such tumors [16]. Later, Yasargil proposed a classification dividing in three types according to tumor dimension [40]. The dimension of the tumor is a parameter that has been further reconsidered by other classification systems [41, 42], but when taken alone fails to depict the complexity of this surgery which is mostly based on the involvement of the neighboring neurovascular structures. Goel [43] in 2002 proposed a new classification system where points are assigned with respect to multiple clinical and radiological parameters enabling. Enabling a division of tumors into three grades. This classification, although really accurate, has not been employed thereafter, maybe for its complexity. Recently, Mortazavi et al. [42] proposed an easy classification system dividing tumors in three classes according to tumor size, optic canal invasion, vascular encasement, brain invasion according to FLAIR sequences in MRI, previous surgery, and radiation. Giammattei et al. [44] retrospectively applied Mortazavi's classification to their series of planum and tuberculum meningiomas and found that it was easy to use and also that it showed a good correlation with visual outcome. Finally, Magill et al. [41] recently proposed a grading scale based on tumor diameter, optic canal invasion, and vascular encasement which proved to be easy to use and able to estimate the visual outcome and extent of tumor resection. The latest classifications [41, 42] could also prove to be useful in order to select the surgical approach (endoscopy vs transcranial approach), but this still has to be validated by further clinical experience.

The literature supports the use of classifications when reporting the results of surgical series because they allow a proper comparison between different surgical approaches and across different series and, when validated by multicentric studies, could allow to predict outcome and complications of surgery.

Surgical approach

A large variety of transcranial approaches have been successfully employed to resect TS meningiomas, i.e., standard pterional approach [4, 17], frontolateral approach [19, 34], unilateral subfrontal [43], bilateral subfrontal [33], supraorbital key-hole approach [35, 45], lateral supraorbital approach [46], frontobasal interhemispheric approach [47, 48], superior interhemispheric approach [49]. Each of the pre-cited approach has its advantages and disadvantages that rise some important point of discussions.

Bilateral or unilateral craniotomy?

The large majority of authors report good results using an unilateral approach [7, 20, 42, 50] which has progressively replaced bifrontal craniotomy due to complications reported in earlier surgical series [33] The paper by Chokyu et al. [33] describes in details the use of the bilateral subfrontal approach. The authors obtained an excellent visual outcome which they attributed to the preservation of the blood supply to the optic apparatus. With a contralateral trajectory, it is indeed possible to visualize the inferior surface of the optic nerve and then preserve the small perforators while this is not possible through an ipsilateral approach (pterional or lateral subfrontal)

[10]. The authors also obtained a very low incidence of postoperative hyposmia and CSF leakage concluding that, considering the development in microsurgical techniques, also the bilateral subfrontal approach could yield very satisfying results. Despite the excellent results presented by the group of Ohata [33], the bilateral approach may carry some risks due to frontal lobes retraction and also to the eventual development of brain edema and venous infarction due to transection of anterior part of superior sagittal sinus [34]. The group of Samii [34] indeed progressively abandoned bilateral craniotomy for tuberculum sellae meningiomas because of the risks linked to transecting the superior sagittal sinus and the associated draining veins resulting sometimes in brain edema and venous infarction with morbidity and mortality avoidable with unilateral approaches according to authors' experience. Other possible disadvantages of bilateral approaches, as described by the group of Gentili [47], which employed a frontobasal interhemispheric route, include the high incidence of postoperative anosmia, a late visualization of optic nerves and carotid arteries, and the opening of the frontal sinus with the associated risk of CSF fistula [47].

The literature supports the use of the unilateral approach for tuberculum sellae meningiomas due to the better chance to achieve a safe resection with limited morbidity. The bilateral approach, although having some theoretical advantages, has been progressively abandoned by the large majority of skull base centers.

Unilateral approach: how to choose the side?

Multiple possibilities are described in literature. The less frequent used option is represented by approaching the tumor from the non-dominant hemisphere in order to avoid complications related to the dominant hemisphere [14]. The relatively low rate of ischemic/hemorrhagic complications (0–5 %) [7, 23, 27, 29, 34] seems to support the more popular strategy of approaching the tumor from the side were vision is worse [31, 46, 51, 52] usually associated to a more important optic canal involvement, with the rationale of performing an early extradural decompression of optic nerve and preserve the non-compromised/less compromised optic nerve. Another possibility is finally represented by approaching the tumor from the side contralateral to the most compromised optic nerve. The rationale behind this approach is represented by the fact that it enables a direct view of the inferomedial aspect of the compromised optic nerve and optic canal which is a blind area during the ipsilateral approach. It could represent then a valid option especially in case of medial optic canal involvement [53]. This approach also implies a minor manipulation of the compromised optic nerve during dissection of tumors from the optic nerve possibly improving visual outcome. [23, 30, 53] The contralateral approach has two major disadvantages: first, there is the possibility of damaging the non-compromised/less compromised optic nerve; and second, there are difficulties in controlling the part of the tumor (if present) lateral to the internal carotid artery. Some authors finally approach the tumor from the side of vascular encasement regardless of optic canal involvement as presented by Mortazavi et al. [42].

The literature supports the use of an ipsilateral approach on the side of the worse vision in order to perform an early extradural optic nerve decompression and also to avoid complications related to mobilization of the non-compromised optic nerve (in cases of a contralateral approach). However, the contralateral approach still remains a valid option. This choice is essentially based on surgeon's experience and preference.

"Vascular surgery" or "skull base" perspective?

Two different surgical attitudes may be proposed when approaching TS meningiomas, namely, a "vascular surgery" perspective and a "skull base" one. Some authors described their surgical experience in resecting such lesions employing a pterional approach and stressed the importance of performing a large opening of the Sylvian fissure from distal to proximal [16, 19, 54]. Jallo et al. obtained visual improvement in 55%, visual stability in 26%, and visual aggravation in 19% of their patients. Similar results, although with a minor percentage (6%) of visual aggravation, were obtained by Li-Hua et al. [19]. However, Li-Hua et al. [19], while proposing this approach, noted cerebral infarctions in 3% of the cases.

This approach is obviously antithetic to skull base approaches that generally include orbital osteotomy [20, 42, 44, 52, 55] to reduce brain retraction and extensive extradural bone work along with an add-on extradural anterior clinoidectomy in selected cases [20, 42, 56].

Another attractive alternative to the standard frontotemporal basal craniotomy approach is the frontolateral minicraniotomy through a suprabrow incision, which is considered to be a minimally invasive key-hole approach that could reduce approach-related morbidity [32]. It is a viable option especially for small-sized tumors that enables excellent visual results along with very satisfying cosmetic outcomes. The minicraniotomy could restrict freedom of surgical movements which can be overcome by the use of endoscope assistance with angulated optics [57].

The results concerning visual outcome obtained by the authors [16, 19] who employ a pterional-transsylvian route appear to be less satisfying when compared with authors proposing a lateral subfrontal access through a skull base approach (standard or minicraniotomy) [32, 42], where the compressive effect of the tumor on the optic nerve is released early along with devascularization of the tumor. This frequently needs only a minimal opening of the proximal part of Sylvian fissure when needed.

The literature supports the use of a skull base approach with the rationale of reducing brain retraction, avoid complications related to a large opening of Sylvian fissure, and performing an early devascularization of the tumor and early decompression of the more involved optic nerve.

Should the optic canal be routinely opened?

This is one of the most controversial issue about tuberculum sellae meningiomas. The incidence of optic canal invasion (OCI) has been, to a certain extent, underemphasized in the current literature and many surgical series neither mention OCI nor analyze its relationship to visual outcome [58]. The incidence of OCI, therefore varies largely in the literature (8–100%) [11]. Some authors reported a very high percentage of OCI in TB meningiomas [2, 7, 12, 58, 59], while other authors reported that it is rarely encountered in TB meningiomas [9, 31]. This large variation can probably be explained by the fact that MRI often fails to identify OCI as reported by some authors [2, 58, 59] who demonstrated that OCI is radiologically detectable only when oblique projections are analyzed to focus on the optic canal anatomy with respect to tumor extent onto the compressed optic nerve. Moreover, although considered midline tumors, tuberculum sellae meningiomas originate in the majority of cases from the lateral end of tuberculum sellae, and very close to the optic canal thus rendering frequent its invasion [2, 6, 58]. The generally high rate of OCI found by these authors seems to justify the policy of clearly identifying this tumor extension and planning appropriately the surgical strategy that focuses on the nerve. The problem with not addressing the intracanalicular part of the tumor could be associated to a higher incidence of residual/recurrent tumor and more importantly to an unimproved/worse vision in the post-operative phase [23, 58]. This attitude, however, seems to be challenged by the comparable good results, in terms of visual outcome and tumor control rates, obtained by the authors that performed optic canal opening only for cases with extensive intracanalicular extension [3, 4, 9, 13, 31]. However, this debate largely depends on practice patterns and determined by the proportion of large tumors in different series.

The literature supports the need of performing adequate imaging to estimate optic canal invasion patterns, namely, MR sequences and projections that focus on the optic canal and the nerve-tumor interface. Given the lack of evidence about frequency and patterns of OCI, the option of a routine extradural optic canal opening or performing this only in selected cases remains to be decided based on practice patterns (dependent on tumor extensions) and surgeon's preference.

Should the optic canal be opened before tumor resection?

Visual aggravation or lack of improvement is still a significant issue in TB meningioma surgery. Some authors have stressed the importance of decompressing the optic nerves before starting tumor resection in order to minimize the optic nerve manipulation [20, 42, 56, 60]. Some authors [56, 60] showed clearly the discolored area intraoperatively that is usually found on the transition of the optic nerve at the falciform ligament. This part of the nerve could be very sensitive to intraoperative manipulation, thus partially explaining the cases where visual aggravation is observed in the post-operative period. The results obtained by Mathiesen et al. [56] and Mortazavi et al. [42] are impressive, with 90% of visual improvement and most importantly, no patient experiencing visual deterioration. Nozaki et al. [60] and Otani et al. [61] also discussed the importance of the timing of optic nerve decompression and found better results in patients where an early decompression had been performed. These results seems to be superior when compared with a large recent series where exploration of optic canal is done at the end of tumor resection [7, 17, 19] or not at all [10, 31]. Some authors also propose to perform extradural clinoidectomy only when there are tumors engulfing or displacing the optic nerves and whenever there are intraoperative difficulties in identifying the ipsilateral optic nerve [52]. The risk (though minimal) of performing extradural clinoidectomy, such as optic nerve damage, vascular injury, CSF leak, and cranial nerve palsy due to the exposition of the anterior wall of the cavernous sinus, also merits consideration [56].

The literature supports the decompression of the optic nerve before starting tumor resection that seems to be associated with excellent results concerning visual outcome, or at least in terms of reducing the rate of visual degradation due to surgery. Nonetheless, this depends largely on the basis of multiple elements like the severity of optic canal invasion, the degree of visual impairment, and also surgeon's confidence with the required technical skills.

Transcranial vs endoscopic approach?

The increasing popularity of endoscopic endonasal approach (EEA) to treat skull base meningiomas is one of the most debated issue within the skull base community. Approaching the tumor from below has some theoretical advantages such as the possibility of early removal of the bone adjacent to the dural attachment, the possibility of a 270° early decompression of the optic canal, early devascularization of the tumor, better visualization and preservation of the superior hypophyseal and ACAs supplying the chiasma, and avoidance of brain retraction [22, 62]. One of the main disadvantages of the EEA is increased risk of CSF fistula due to a challenging reconstruction. However in skilled hands, complications of this

nature have considerably reduced [63, 64]. The other disadvantages include the difficulties in removing tumor located at superior and lateral to optic canal, limited surgical freedom, and the inability to gain adequate vascular control in case of major vascular injury [62, 65–67]. EEA has been associated with not insignificant sinonasal morbidity with the potential to adversely affect patient's quality of life [68, 69]. The extended EEA requires a more aggressive resection of nasal structures such as the middle turbinate and increased mobilization of nasal mucosa. When specifically addressing planum/tuberculum sellae meningiomas, the long-term nasal QOL after EEA was found to be significantly decreased [70]. Anosmia can occur with transcranial approaches as well as EEA [20, 29, 68, 71].

Some authors compared transcranial and endoscopic approach obtaining better visual outcomes with EEA and attributed these results mostly to early optic canal decompression and preservation of perforating artery to the optic apparatus [11, 72–74]. A recent meta-analysis [75] also showed better visual outcome with EEA although it resulted in a higher rate of arterial injury and CSF fistula. This meta-analysis has however had some limitations, including inter-group approach selection biases, thus rendering interpretations of the results somewhat difficult. However, the comparison between the results offered by the two approaches may be sometimes unfair because there is still a tendency to treat complex tumor (in terms of dimension, vascular encasement, optic canal invasion) with transcranial approach as recently showed by Magill et al. [41]. Some authors have progressively proposed some criteria to help the surgeon to decide between transcranial and endoscopic approach, thus trying to tailor the surgery. de Divitiis et al. [76] were the first to propose some clear criteria to propose EEA, namely, small or medium size midline tumors, with limited dural attachment and no vascular encasement or calcifications. Similarly, Fatemi et al. [77] proposed to address by an endonasal route tumor inferior to 3 cm, without lateral extension in respect to carotid arteries and without vascular encasement. Bowers et al. [25] recommended EEA for tumor smaller than 3 cm, medial to carotid arteries, with dural attachments inferior to optic nerve in the optic canal and not extending beyond clinoid processes or inferiorly into the sella. The authors also suggested the endoscopic approach for elderly patients with significant comorbidities where GTR was not the aim of surgery. Other authors [66, 78, 79] later confirmed the limited possibilities of removing endoscopically the tumor extending lateral to internal carotid arteries and underlined that anterior communicating artery complex dissection can be performed while lateral (internal carotid artery (ICA)) encasement is still a limit of this approach. Schwartz et al. [80] considered EEA to be contra-indicated in tumors that extend laterally beyond ICA bifurcation or with a clear encasement of ICA, anterior cerebral artery complex, and optic nerves if the goal of surgery is a GTR. If the aim of surgery is a subtotal resection (STR), these could be considered as relative contra-indications. The authors also demystified the presence of a "cortical cuff" (brain juxtaposed between the tumor and adjacent cortical vessels) and brain edema that according to the authors should not be considered as a contraindications to EEA in experienced hands.

The group of Gentili [1] developed similar criteria adding as relative contra-indications to EEA a significant optic canal extension, a wide dural attachment along the anterior cranial fossa, an extensive hyperostosis, and a significant perilesional brain edema. Kshettry et al. [81], also stated that tumor located superiorly to the optic nerve is better addressed transcranially with tumor located laterally to the optic nerve being a limit for EEA. They underlined that prefixed optic chiasm is a very good indication for EEA given the difficulties in accessing the sellar region transcranially and stated that partial ICA encasement, when arachnoid and CSF are still around the vessel, should not be considered as a formal contraindication to EEA.

Kong et al. [74] showed that EEA could be a better approach in cases of tumors that tend to extend deep in the sella turcica, suggesting to evaluate the angle from the frontobasal line to the sella. These authors also found that optic canal invasion is a good indication for EEA due to the possibility of performing an early decompression of the medial part of the canal. Song et al. [11] basing on the analysis of the location of recurrence, found that tumors with an inferior origin and an elongated tuberculum sellae are an ideal indication to EEA, while lesions extending laterally are better addressed transcranially. This seems reasonable given the fact that visualization of tumor located in the pituitary fossa is poor with transcranial approach.

To summarize, it seems that the relative contraindications to EEA should be probably adapted to the surgical experience and comfort of the surgical team [22]. A very interesting recent paper by Magill et al. [41] which included the results of two centers (one more biased towards endoscopic approach and the other towards transcranial approaches) failed to show a significant difference in visual outcome (neither visual improvement nor visual worsening) between EEA and transcranial approach when the tumor are stratified according to their complexity (based on diameter, optic canal invasion, and vascular encasement). The authors accordingly proposed that the decision of the surgical approach should be tailored on the single case considering anatomy, surgeon's experience, and also patients' expectations.

The literature supports the use of the transcranial approach because it is the technique that is performed on a regular basis by the majority of skull base units worldwide with excellent results and with no limitations with respect to tumor size or vascular encasements. The surgery through an endonasal route remains restricted to the few skull base units known for EEA with limitations with respect to tumor morphology and advantages to visual function in selected cases.

Summary

- Patients should receive a preoperative radiological examination including MRI and CT scan. The first post-operative MRI should be performed within 3 months and then repeated yearly.
- A detailed neuro-ophthalmological examination including visual acuity, visual field examination, optic fundoscopy, OCT, and examination of oculomotor function should be performed before and usually 3 months after surgery. Use of scoring system, such as the VIS, should be encouraged to allow comparison between the different surgical series.
- A complete preoperative and post-operative endocrinological assessment should be performed.
- We strongly encourage the use of classifications when reporting the results of surgical series to allow the comparison between different surgical approaches and across different series.
- The literature supports the use of the unilateral approach. An ipsilateral approach on the side of the worse vision is the preferred choice of the majority of authors.
- The literature supports the use of a skull base approach with the rationale of reducing brain retraction, performing an early devascularization of the tumor and an early decompression of the more involved optic nerve. Extensive opening of Sylvian fissure is unnecessary.
- Given the lack of evidence about frequency and patterns of OCI, the option of a routine extradural optic canal opening remains to be decided based on practice patterns (dependent on tumor extensions) and surgeon preference.
- The literature supports the decompression of the optic nerve before starting tumor resection that seems to be associated with excellent results concerning visual outcome or at least in terms of reducing the rate of visual degradation due to surgery.
- The transcranial approach still remains the preferred choice in most neurosurgical centers. The surgery through an endonasal route remains restricted to the few skull base units known for EEA, with limitations with respect to tumor morphology and advantages to visual function in selected cases.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this type of study, formal consent is not required. This article does not contain any studies with human participants performed by any of the authors.

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