A reappraisal of surgery for orbital tumors. Part I: extraorbital approaches

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Orbital lesions are variable in nature and location. Their management can be challenging, and surgical intervention is often needed. Although a significant percentage of these tumors are treated by the ophthalmologist alone, collaboration with a neurosurgeon is often required, especially for tumors that are located deep within the orbit, are large, or have an intracranial extension. Technical advances and modifications in surgical technique have decreased surgery-related morbidity and increased its success. The authors describe their rationale in the choice of a surgical approach, the surgical techniques for extraorbital approaches, and the new surgical adjuvants.

KEY WORDS • orbital tumor • tumor excision • surgical approach

Since our initial report on surgery for orbital tumors in 1976,^{10,16} there have been various technical advances and modifications in the surgical management of these lesions.^{1,3,4,8,11,13,19,21,23} Having treated over 1000 cases of orbital tumors, our experience has broadened. Based on this experience we will discuss our current surgical strategy in the management of orbital tumors, with an emphasis on the different surgical approaches.^{15,17,18}

TYPES OF SURGICAL APPROACHES

There are two types of surgical approaches: the transorbital approaches, which are undertaken by the ophthalmologist alone, and the extraorbital approaches, which are best performed in collaboration with a neurosurgeon or an ENT surgeon.

Transorbital Approaches

There are four primary transorbital approaches: 1) the anterior orbitotomy without osteotomy (superior [eyelid, supraorbital, or subbrow incision] or inferior [transconjunctival, subciliary, or lower-eyelid incision]) or with osteotomy of the superior orbital rim (for large lesions); 2) lateral orbitotomy; 3) medial orbitotomy; and 4) a combination of the lateral and medial orbitotomies.

Abbreviations used in this paper: ENT = ear, nose, throat; MR = magnetic resonance.

Extraorbital Approaches

There are two primary extraorbital approaches: 1) the frontotemporal approach with or without orbital osteotomy; and 2) the inferior orbital approach.

CHOICE OF SURGICAL APPROACH

Computerized tomography and MR imaging have contributed considerably to the understanding of the tumoral relationships, as well as the size, location, and possible nature of the lesion. All these factors are paramount in determining the surgical approach. The radiological characteristics on both coronal and axial cuts of computerized tomography scans and MR images are reviewed.

In general anterior lesions are treated via transorbital approaches, whereas lesions of the posterior third are best managed via extraorbital approaches. This distinction is not absolute, because some posterior lesions can be approached via extended or combined transorbital approaches, and lesions of the middle third of the orbit are easily accessible via the extraorbital approaches. In addition to location, other factors, such as the size of the lesions, the goal of the surgery (biopsy, debulking, or gross-total excision), and the characteristics of the tumor, must be considered when selecting an approach.

Anterior lesions are approached via anterior orbitotomy (superior or inferior). For large anterosuperior lesions an osteotomy is additionally performed. Lateral lesions are approached via a lateral approach, which can be further

extended posteriorly by drilling the sphenoid wing to allow access to posterolateral lesions,⁴ although an extraorbital approach may be preferable. Small or anteriorly placed medial lesions are approached via medial orbitotomy. Large or posteriorly located medial lesions are excised via a combined lateral and medial orbitotomy: the globe is prolapsed laterally into the defect to improve medial exposure. Alternatively a frontoorbital approach can be used when resecting these lesions.

Lesions located inferiorly and posteriorly, between the optic nerve and inferior rectus, are resected via an inferior orbital approach, which is performed in collaboration with an ENT surgeon. Tumors involving the ethmoid bone and sinus should also be resected in conjunction with an ENT surgeon. Endoscopic techniques can be an effective adjunct to an orbital approach to medial or inferior lesions.^{3,21}

Lesions with intracranial extension are best approached via a frontoorbital approach. This approach is also used for lesions within the optic canal and apex. Adding an orbital osteotomy improves the exposure, especially in cases with large tumors or when the optic canal needs to be drilled. The orbital osteotomy also helps to decrease the amount of brain retraction required. Lesions of the sphenoid wing and those located posterolaterally (superior orbital fissure) are best approached via a pterional approach, usually without an orbital osteotomy.

SURGICAL TECHNIQUES

Inferior Orbital Approach or Posteroinferior Orbitotomy

Technically it is most difficult to access orbital lesions located in the apex (Fig. 1), particularly those medial and inferior to the optic nerve. This location precludes the use of a craniotomy or a posterior lateral orbitotomy because of the vital structures encountered in the surgeon's view. Because it is also a difficult area to approach for an anter-

Fig. 1. Diagram showing the orbital apex. Many important structures are gathered in a small area, making the lesions of this orbital area the hardest to access. A = artery; inf = inferior; N = nerve; Sup = superior; V = vein. Reprinted with permission from Maroon and Kennerdell.

omedial orbitotomy, even when a lateral osteotomy is performed, we were prompted to introduce the posteroinferior orbitotomy for apical tumors inferior to the optic nerve.¹¹

This approach can be used for posteroinferior orbital tumors but not antero-inferior orbital tumors because of the infero-orbital neurovascular bundle. This approach is conducted in conjunction with an ENT specialist and consists of a standard Caldwell–Luc excision on the side of the tumor.

The approach begins with a horizontal incision in the gingiva, which exposes the antero-inferior wall of the maxillary sinus. An opening through the wall is made into the sinus itself. The maxillary sinus mucosa is then removed through the opening, exposing the orbital floor.

The inferior orbital bone prominence is identified, and the area that contains the inferior neurovascular bundle is avoided. The posteroinferior floor is then removed.

Before entering the orbit, the surgeon places the operating microscope in the field looking through the maxillary sinus opening exposed via the Caldwell–Luc approach. The inferior rectus muscle is identified and gently retracted to one side. The field is illuminated as the surgeon gently moves the inferior rectus to one side or the other and searches for the tumor. When the tumor is found, the long-tipped cryoprobe is used to grasp it.^{8,19} The cryoprobe is then gently maneuvered back and forth while the surgeon teases away the surrounding tissue by using long cotton applicators and microsurgical dissecting instruments (usually a spatula, duck-billed dissector, or nerve hook). The tumor is removed through the Caldwell–Luc incision, and the inferior rectus is then smoothed back into position. Closure of the bony orbit is not required, and the Caldwell–Luc incision is then closed along the gum line with No. 4-0 absorbable sutures. Usually a nasal–antral window is opened to maintain drainage for the maxillary sinus.

Transcranial Approach

The transcranial approach in which the orbital rim is preserved was initially advocated by Dandy⁵ and has been subsequently modified.^{7,14,20} The transcranial approach with orbital osteotomy was initially described by Frazier⁶ in 1913, and it underwent several modifications.^{2,9,22} The transcranial approach targets intraorbital lesions through the roof and lateral walls of the orbit. It is based around the sphenoid ridge, with the exposure tending more toward the roof or the lateral wall of the orbit, depending on the location of the lesion. This approach is ideally suited for apical lesions (reached via the orbital roof) and superior orbital fissure lesions (reached via the lateral wall of the orbit). Optic nerve gliomas and meningiomas are examples of apical lesions. Hemangiomas are typical superior orbital fissure lesions. For sphenoid wing meningiomas the approach is similar to that used to reach lateral lesions, but because they can extend medially into the optic canal, they can be treated via a combined approach.

In this approach the initial surgical steps are similar for the various lesions, with later variations depending on the target (Figs. 2 and 3).

The patient is placed in a supine position. The head is kept straight in cases of apical lesions or turned to the

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Fig. 2. Diagrams showing the various steps of the posteroinferior orbitotomy. Reprinted with permission from Kennerdell, et al. *Practical Diagnosis and Management of Orbital Disease*. Boston: Butterworth-Heinemann, 2001.

opposite side for lateral approaches to the orbit. We use a bicoronal or a question mark-shaped incision behind the hairline that requires minimal shaving of the hair. The question mark-shaped incision is ideal for lateral lesions, but it can also be used for superior apical lesions. In the latter case, the incision has to extend from below the zygoma to the midline or slightly beyond it to allow medial exposure of the orbital roof. Because an interfascial dissection is performed through the temporalis fascia to allow for the temporalis muscles to be reflected posteriorly and improve the exposure, the frontalis branch of the facial nerve is not jeopardized.

The sphenoid wing is partially drilled to expose the frontal and temporal dura, and a frontotemporal craniotomy is performed. It extends close to the midline for superior apical lesions. If the frontal sinus is opened, it is exenterated, packed with fat or muscle, and sealed with a pericranial flap. An orbital osteotomy (resection of the superior and lateral orbital rim) and excision of the adjacent orbital roof are performed in cases in which extensive retraction of the cerebral hemispheres is required; otherwise, only the orbital roof is removed and the orbital rim is left intact. The osteotomy, which will allow a better exposure and require less brain retraction, is favored for resection of superior apical lesions. Alternatively, the cranial bone and orbital rim can be removed in one piece.

The superior orbital fissure is unroofed, and the orbital roof removed to expose the periorbital. The amount of bone removal will vary depending on the location of the lesion. The optic canal is decompressed for lesions involving the optic nerve (optic nerve gliomas and meningiomas). We will discuss separately the surgical steps for the various lesions: superior orbital fissure, optic canal, and sphenoid wing tumors.

Frontotemporal Craniotomy Approach to Superior Orbital Fissure Tumors. In our experience, hemangiomas and neurofibromas are the most common tumors located

Fig. 3. Diagrams showing the frontoorbital approach to the orbit (Parts I and II). *Upper: Part I.* A bicoronal incision is made, and the temporalis muscle is dissected off the skull (A). The periorbital is then freed, and burr holes are made for the craniotomy (B). Note that the osteotomy is removed in one piece with the frontal bone flap in this particular illustration (C). *Lower: Part II.* The dura is freed from the bone flap (D and E). The bone flap is removed in one piece along with the orbital rim (F). Removal of the orbital rim facilitates drilling of the optic canal (G). Reprinted with permission from Maroon and Kennerdell.

in the superior orbital fissure. After confirming the precise location of the tumor by MR imaging in axial, sagittal, and coronal planes, the craniotomy is performed, extending mostly over the temporal tip, and a small amount of frontal bone removed. Lateral-to-medial extradural dissection is performed. The lateral superior orbital bone is removed using a drill and rongeur to allow the periorbital to be visualized, until the meningo-orbital band is encountered and transected. Immediately medial to this is the superior orbital fissure. The periorbital is incised horizontally between the lateral and superior rectus muscles. The orbital tumor is exposed using malleable brain retractors, microsurgical dissectors, and long cotton-tipped applicators. With small microcottonoids, the soft tissue and nerves of the oculomotor complex are gently displaced from the surface of the tumor. If necessary, reduction can be accomplished using bipolar coagulation on low settings, a microsurgical Cavitron ultrasonic suction aspirator, or a carbon dioxide laser on milliwatt setting. At this point, an ophthalmic cryoprobe may be attached to the tumor to facilitate its extraction and microdissection from any adhesions. Although reconstruction of the orbit is not required, a titanium mesh cranioplasty helps build up that area and compensate for atrophy of the temporal muscle. This will minimize the cosmetic defect. The craniotomy is closed in standard fashion.

Frontoorbitotemporal Approach to Optic Nerve Tumors. The skin incision extends from the ipsilateral zygomatic process on one side to the temporal line on the opposite side. The skin flap is elevated anteriorly to expose the supraorbital nerve. The craniotomy involves mostly the frontal bone and extends medially, close to the midline. The portion of orbital bone that has been cut is removed either as a separate piece or along with the frontal bone flap.

The remainder of the orbital roof is removed using rongeurs. The optic canal is unroofed using a diamond drill and copious irrigation to avoid heat-induced damage. The anatomical relationship of the ethmoid sinus medially and the pneumatized anterior clinoid process laterally must be kept in mind to avoid cerebrospinal fluid leakage (Fig. 4). If these cavities are entered, they should be packed with muscle. The optic nerve is freed from its adhesions to the intracanalicular dura mater. If the dura and optic nerve appear free of tumor, the optic nerve is transected proximally as it passes through the retracted dura into the optic canal. A gush of fluid is seen as the dura is incised. The nerve is then grasped, elevated, and the fine trabecular connections between the nerve and the dura of the optic canal are then sharply transected using microscissors to the anulus of Zinn.

Once the periorbital is exposed, the frontal branch of the trigeminal nerve is seen overlying the superior rectus and levator muscles. In cases of optic nerve lesions, the exposure is made medial to these muscles to avoid injuring the nerves of the extraocular muscles and ciliary ganglion. Occasionally, large tumors may create a corridor between the lateral rectus and levator muscles that is used to assist in the resection.

A very large tumor may displace or markedly attenuate the rectus muscles as they are stretched over the dome of the lesion. It is essential that these muscle fibers be delin-

Fig. 4. Diagram showing the medial relationship of the optic canal with the ethmoid air cells. Also demonstrated is the lateral relationship of the apex to the sphenoid bone and temporal tip. Reprinted with permission from Maroon and Kennerdell.

eated and then gently retracted using tapered brain retractors to facilitate tumor dissection. Intraorbital dissection may be facilitated using four 4-mm tapered retractors and long cotton-tipped applicators to displace the fat. Four blades are inserted: one retracts the levator and superior rectus muscles laterally; a second is used to dissect through the orbital fat and retract the fat medially; a third is placed on the posterior aspect of the globe to retract it anteriorly; and a fourth is placed deep in the apex of the orbit above the nerve or tumor, which is identified by dissecting through the epidural fat and, at times, by finger palpation.

The optic nerve-globe junction is identified. After bipolar coagulation of fine surface vessels, the nerve is transected within 2 to 3 mm of the globe. If the tumor is very large (optic nerve gliomas often have prominent cysts), an ultrasonic aspirator is used to puncture the tumor and suction its nonsolid contents. Forceps with teeth or a hemostat may then be used to grasp the transected end of the nerve for elevation and subsequent microdissection of the attachments circumferentially. Occasionally the tumor can be sectioned proximal to the anulus and pulled through. More commonly the anulus must be opened and the residual tumor subjected to a bipolar coagulation.

As the elevation and retraction approach the apex of the orbit, it is often possible for the surgeon to dissect the optic nerve sharply from its sometimes dense attachment to the anulus of Zinn—if not performed initially—and then pull the nerve through the anulus into the orbit without opening the anulus itself. If the tumor is involved with the anulus, it may be necessary to open this structure, which then can be resutured after bipolar coagulation of any visible tumor remnants at the completion of the operation.

In this fashion, the entire optic nerve, with its contained tumor, is removed in one piece and standard histological inspection of the proximal end is performed to confirm the presence of tumor-free margin as suspected from visual examination. If the distal aspect of the optic nerve is found to be free of tumor, it is not necessary to open the dura for intradural inspection. The dural opening is plugged with a temporalis graft. Additional intracranial surgery is essential if preoperative gadolinium-enhanced MR imaging has identified any abnormalities in the basal dura or proximal enlargement of the optic nerve or chiasm, or if there is proximal involvement is observed on the frozen pathological specimen. If there is intradural involvement, then the dura is opened and the intradural optic nerve inspected. The optic nerve is sectioned close to the optic chiasm and resected.

Frontotemporal or Pterional Approach for Sphenoid Wing Meningiomas. This approach, which is used to resect meningiomas of the sphenoid bone, is similar to the frontotemporal approach for superior orbital fissure lesions; however, the lesser and greater sphenoid wings are drilled away because they are invaded by tumor. For extensive meningiomas, a frontoorbital craniotomy may be used to obtain better exposure of the intracranial components.

A question mark-shaped incision is used. The skin flap is elevated using an interfascial dissection, the temporalis muscle is reflected posteriorly, and the abnormal sphenoid bone becomes visible. The involved sphenoid bone is removed using a high-speed drill.

Using tapered brain retractors, the frontal lobe is retracted and the orbital roof is removed with a diamond drill. The involved optic canal is unroofed if visual compromise is present. Drilling of the anterior clinoid process and the optic canal roof is conducted with copious irrigation to avoid heat-induced injury to the optic nerve.

The tumor may also invade the periorbita and lateral orbit. The periorbital fascia is visualized and an incision is made. The involved periorbita may be removed. The superior rectus muscle is retracted medially and the lateral rectus muscle is retracted laterally by using tapered brain retractor in both cases. The lateral orbital component of the sphenoid wing meningioma is debulked, taking care to avoid the extraocular muscle nerves. If the tumor is adherent to adjacent structures, it is left behind and postoperative irradiation is undertaken in selected cases.¹²

A small frontotemporal craniotomy is added if any meningeal enhancement is demonstrated on MR imaging. The intradural tumor and the underlying dura are resected.

SURGICAL ADJUVANTS

In addition to the use of the microscope, other more recent modalities, such as neuronavigational techniques, endoscopy, and stereotactic radiosurgery, have helped us in the surgical management of orbital tumors.

Generally speaking, neuronavigational systems offer little advantage in the treatment of most orbital tumors.¹³ In cases of deep apical lesions, which are difficult to access via microsurgical approaches, these systems may be of considerable assistance. In specific cases of apical hemangioma reached via the Caldwell–Luc approach, we

were able to localize confidently the precise site of entrance from the maxillary sinus into the orbit. In another case of a patient harboring a superior orbital fissure tumor, neuronavigation was also useful in defining precisely where to open the dura when palpation or direct visual inspection could not readily identify the tumor.

As previously mentioned, endoscopic techniques have evolved dramatically and can be an effective adjuvant to approaches to orbital lesions adjoining the ethmoid or maxillary sinuses.^{3,21}

Stereotactic radiosurgery^{1,23} is also used in a complementary fashion with excision. In cases of lesion of the sphenoid wing, particularly meningiomas, we no longer attempt radical removal of lesions that invade the cavernous sinus and superior orbital fissure because of the attendant severe ocular-related complications that can occur. Instead, we aggressively remove all intraorbital and intracranial tumor, preserving the cranial nerves in the cavernous sinus and superior orbital fissure; as soon as the wound has healed, we recommend radiation therapy. If the lesion is less than 2.5 to 3 cm in diameter and can be precisely targeted to avoid damage to the optic nerve or chiasm, gamma knife surgery is recommended. Otherwise, standard fractionated irradiation is administered.

CONCLUSIONS

Because of the advances in neuroimaging and microsurgical skull base approaches, we are able to access areas that could not be reached without causing considerable morbidity years ago. Most tumors confined to the orbit can indeed be approached via an extradural approach either from the medial-lateral-superior or inferior aspect of the orbit. Intraoperative neuronavigation systems may add substantially to localization of lesion, particularly those located in the orbital apex. Endoscopy is an adjunctive tool useful in selected cases. Finally, in those cases in which the tumors cannot be completely excised, stereotactic radiosurgery provides a useful adjuvant for tumor suppression and control of future growth.

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