Microscopic versus endoscopic approaches for craniopharyngiomas: choosing the optimal surgical corridor for maximizing extent of resection and complication avoidance using a personalized, tailored approach

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Resection remains the mainstay of treatment for craniopharyngiomas with the goal of radical resection, if safely possible, to minimize the rate of recurrence. Endoscopic endonasal and microscopic transcranial surgical approaches have both become standard methods for the treatment for craniopharyngiomas. However, the approach selection paradigm for craniopharyngiomas is still a point of discussion. Choosing the optimal surgical approach can play a significant role in maximizing the extent of resection and surgical outcome while minimizing the risks of potential complications. Craniopharyngiomas can present with a variety of different sizes, locations, and tumor consistencies, and each individual tumor has distinct features that favor one specific approach over another. The authors review standard cranial base techniques applied to craniopharyngioma surgery, using both the endoscopic endonasal approach and traditional open microsurgical approaches, and analyze factors involved in approach selection. They discuss their philosophy of approach selection based on the location and extent of the tumor on preoperative imaging as well as the advantages and limitations of each surgical corridor, and they describe the operative nuances of each technique, using a personalized, tailored approach to the individual patient with illustrative cases and videos.

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CRANIOPHARYNGIOMAS are rare, slow-growing neoplasms that originate from a region of embryonic tissue around the pituitary stalk, with an incidence of 0.13 cases per 100,000 people every year. They represent approximately 2%–5% of all primary brain tumors and have a bimodal presentation in children aged 5–14 and adults aged 55–65 years.⁴ Although craniopharyngiomas are histologically benign, they threaten to compress and impair vital neighboring neurovascular structures, including the optic nerves and chiasm, hypothalamus, and pituitary stalk and gland. Because of their intimate involvement with critical structures, resection of these lesions

can be associated with considerable risks of morbidity. Nevertheless, surgery remains the first line of therapy and offers the best chance of radical resection and oncological cure.^{16–20,28,56,59} Advances in skull base approaches, modern microsurgical and endoscopic techniques, neuroimaging, and hormone replacement therapy, however, have allowed for safer gross- or near-total resection in the modern neurosurgical era with gross-total resection rates ranging from 72.7% to 90%.^{14,18,19,22,24} In cases where tumor is adherent to critical structures such as the optic nerve, hypothalamus, or perforating vessels, achieving a maximal safe resection or near-total resection (> 95%) is the goal for preservation

ABBREVIATIONS EEA = endoscopic endonasal approach.

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of neurological function. Although craniopharyngiomas are not strictly tumors of skull base origin, their anatomical relationship with critical basal neurovascular structures often requires a skull base approach to maximize the surgical corridor for optimal oncological resection.⁴⁶

A variety of different skull base approaches can be used to access craniopharyngiomas, each with distinct advantages and limitations. Traditional open transcranial approaches include midline approaches (transbasal subfrontal and frontobasal interhemispheric), anterolateral approaches (pterional, orbitopterional, orbitozygomatic, frontolateral, and supraorbital eyebrow), and lateral approaches (combined petrosal and subtemporal).^{19,20,24,44,47,54} Alternatively, the transnasal route via the extended transsphenoidal (microsurgical) approach offers a direct trajectory to the sellar and suprasellar space for strictly midline tumors.^{13,29,40,41} More recently in the last decade, the purely extended endoscopic endonasal approach (EEA) via the transplanum transtuberulum corridor has become a useful and effective route for removing craniopharyngiomas in the retrochiasmatic space extending superiorly into the third ventricle.^{5,7–10,22,23,31,33,35–37,42,45} Lastly, purely intraventricular craniopharyngiomas situated in the third ventricle and/or lateral ventricles may be better accessed with transcortical or transcallosal intraventricular approaches.

Approach selection is largely dependent on tumor location, extent of pathology, tumor consistency, relationship to the optic chiasm, relationship to the pituitary stalk, involvement of the third ventricle, history and details of prior surgeries, and lastly, the surgeon's preference based on personal experience and comfort. Various authors have classified craniopharyngiomas based on the location, their relationship to the pituitary stalk, or their position along the vertical hypophyseal axis.^{33,53,54} While these classification systems can assist with surgical approach selection, it is important to recognize the limits of such systems, as it is possible for craniopharyngiomas to extend into multiple regions, which increases the surgical complexity. Accordingly, a combined approach using more than one corridor may be necessary for extensive craniopharyngiomas involving multiple anatomical compartments that are not amenable to one isolated approach. Therefore, a personalized, tailored approach to the individual tumor based on multiple factors is crucial in determining the treatment strategy.

In general, when selecting the optimal approach based on anatomical location, consideration should be taken to choose an approach that not only has the shortest direct route to the tumor, but also optimizes exposure and visualization of the tumor interface with critical structures in order to avoid damage to surrounding vital structures, such as the pituitary stalk, hypothalamus, optic chiasm, and perforating vasculature.⁴⁶ Although there is debate between open transcranial (above) and endoscopic endonasal (below) approaches for various skull base lesions, there has been an increased acceptance of EEA for suprasellar and retrochiasmatic craniopharyngiomas.^{5,7–10,22,23,31,33,35–37,42,45} In a recent systematic literature review of surgically treated craniopharyngiomas, the endoscopic cohort had a significantly greater rate of gross-total resection (66.9% vs 48.3%) and improved visual outcome (56.2% vs 33.1%)

than the open transcranial cohort, while the rate of CSF leakage was higher in the endoscopic cohort (18.4% vs 2.6%). However, this type of study presents various limitations due to the heterogeneity in the literature. For example, the tumor diameter was greater in the transcranial group, which suggests that smaller midline tumors may have been preferentially selected for endoscopic endonasal surgery.

The goal of this paper is to review 5 main categories of microscopic and endoscopic operative approaches for craniopharyngiomas (anterolateral transcranial, midline transcranial, extended transsphenoidal, intraventricular, and lateral transcranial), discuss advantages and limitations of each that factors into optimal approach selection, and present technical pearls and nuances with respect to maximizing tumor resection and avoiding complications, with clinical case correlates and illustrative operative videos.

Anterolateral Transcranial Approaches

The anterolateral transcranial approaches expose the suprasellar region via an anterolateral trajectory, usually through a transsylvian or unilateral subfrontal corridor. These generally include the pterional (frontotemporal), orbitozygomatic, and lateral supraorbital (frontolateral) approaches.^{20,24,46,59} While all of these approaches typically use a curvilinear incision behind the hairline, the latter group of supraorbital approaches can also be performed with smaller eyebrow or eyelid incisions.^{15,21,50,57} These are familiar approaches that provide a short route to the suprasellar region and are particularly useful for tumors that exhibit lateral extension into the sylvian fissure. Recently, Gerganov et al.²⁴ reported excellent outcomes with an 87% rate of gross-total resection of extensive craniopharyngiomas using a more simple frontolateral craniotomy. While there are a variety of anterolateral approaches, we prefer the one-piece modified orbitozygomatic approach. This approach is a natural extension of the pterional approach which provides a more basal (inferior-to-superior) surgical trajectory, increases the corridor of exposure, shortens the distance to the target, and improves surgical freedom (maneuverability of instruments) while minimizing brain retraction.

Modified One-Piece Orbitozygomatic Approach: Technical Pearls and Clinical Case Correlate

With the patient in the supine position, the head is rotated approximately 30° to 45° to the contralateral side with slight extension of the neck so that the malar eminence is at the highest point to facilitate relaxation of the frontal lobes away from the skull base. A curvilinear frontotemporal incision is made behind the hairline, and the scalp is elevated in a 2-layer fashion. The galeocutaneous layer is initially elevated followed by elevation of a vascularized pedicled pericranial flap. Interfascial dissection of the temporalis muscle is performed to protect the frontotemporal branch of the facial nerve. The temporalis muscle is mobilized inferiorly toward the zygomatic arch, leaving a myofascial cuff at the superior temporal line for reattachment at the time of closure. At this juncture, a variety of different craniotomies can be performed (pterional, orbi-

tozygomatic, or supraorbital) depending on the surgeon's choice.

We prefer a one-piece modified orbitozygomatic craniotomy that involves a frontotemporal pterional bone flap that incorporates the orbital rim and a small portion of the zygoma (Fig. 1).²⁵ This technique allows for a more simplified and efficient cosmetic closure with only a single bone flap to reconstruct without having to plate separate orbital osteotomy fragments. To facilitate the one-piece technique, it is paramount to create a generous MacCarty bur hole that exposes 3 components: 1) frontal lobe dura, 2) orbital roof, and 3) periorbital.³ The orbital rim is disarticulated with the frontotemporal bone flap as one piece using an osteotome and fracture technique. An orbital osteotomy is made just lateral to the supraorbital notch, inferior to the frontozygomatic suture, and across the orbital roof through the MacCarty bur hole. To maximize pretemporal and transsylvian exposure, we drill off the sphenoid wing down to the superior and lateral walls of the orbit toward the orbital apex at the level of the meningo-orbital band. After opening the dura, wide splitting of the sylvian fissure and opening of the optic cisterns are performed to promote brain relaxation and to identify the optic nerves, chiasm, internal carotid artery, oculomotor nerve, and tumor. Tumor removal is generally performed through a variety of surgical corridors between nerves and vessels including the prechiasmatic (subchiasmatic), optico-carotid, and carotid-oculomotor windows. A more lateral trajectory can be achieved using a pretemporal corridor. Here, the temporal bridging veins to the sphenoparietal sinus are coagulated and divided so that the temporal lobe can be mobilized posteriorly. This maneuver provides an excellent lateral trajectory exposure to the ipsilateral tentorial incisura, oculomotor nerve, carotid artery, and optic nerve.

A large number of craniopharyngiomas are in the retrochiasmatic location, under the chiasm and extending up into the third ventricle. When approached from above with an orbitozygomatic approach, a retrochiasmatic tumor can often be hidden from the operative view, especially with a prefixed chiasm, and trans-lamina terminalis exposure would be necessary to access the tumor. Working in narrow corridors between the nerves and arteries can be surgically challenging with increased risk of neurovascular manipulation of critical structures. Moreover, this approach provides poor visualization of the undersurface of the chiasm where critical perforators supply the visual apparatus. There is also poor visualization of the critical plane between the tumor capsule and the hypothalamus, a location where tumor is often adherent. Dissection of this plane most often results in blind manipulation, thus increasing the risk of potential injury.

Illustrative Case 1: Orbitozygomatic Approach for Lateral Transsylvian Extension

This 69-year-old man presented with increased weakness on the left side and progressive falls along with a left homonymous hemianopsia. MRI demonstrated a large cystic lesion occupying the anterior skull base, suprasellar region, and interpeduncular fossa with lateral extension into the right sylvian fissure causing symptomatic com-

FIG. 1. One-piece modified orbitozygomatic craniotomy. **A:** The patient is positioned supine with head turned to contralateral side about 30° to 45°. Curvilinear skin incision is made behind the hairline. **B and C:** A frontotemporal craniotomy incorporates the orbital rim and upper zygoma bone as a single bone flap. A Medpor Titan implant is used to reconstruct the pterion defect at the time of closure (**B**). **D:** Extensive removal of the sphenoid wing allows a basal trajectory to the parasellar region.

pression on the right temporal lobe, cerebral peduncle, and optic tract (Fig. 2). Based on the extent of lateral extension into the sylvian fissure, a modified orbitozygomatic approach was chosen for transsylvian exposure and pretemporal access to visualize the tentorial incisura. EEA would not be favorable for safe exposure in this particular case because of the tumor location lateral to the carotid artery and extension into the sylvian fissure.

After wide splitting of the sylvian fissure and posterior mobilization of the temporal lobe, we identified the large, greenish-colored, cystic craniopharyngioma situated between the temporal lobe and the internal carotid artery (Fig. 3A). There was also a solid, calcified lesion in the prechiasmatic cistern compressing both optic nerves (Fig. 3B). We then proceeded to dissect the cystic tumor from the sylvian fissure that was located lateral to the carotid artery. The cyst wall was eventually entered and greenish fluid with cholesterol crystals was expressed. Care was taken not to decompress the cyst too quickly so that enough intracystic turgor remained to provide a “surgical handle” and countertraction for continued microsurgical dissection off of critical structures. The cyst wall was peeled off of the temporal lobe on the lateral side and off of small perforating vessels on the medial side. A small microscopic remnant of the cyst wall was left due to strict adherence to perforators coming off of the posterior communicating artery and anterior choroidal artery. After decompression of the cerebral peduncle, the oculomotor nerve was visualized along with the posterior cerebral artery, superior cerebellar artery, and basilar artery (Fig. 3C and D). A near-total resection was achieved, leaving adherent tumor residue to preserve critical neurovascular structures and perforators.

Postoperatively, the patient had improved vision and transient worsening of weakness on the right side that re-

FIG. 2. Illustrative Case 1 imaging. **A–C:** Preoperative sagittal (A) and coronal (B) T1-weighted, and axial FLAIR (C) MR images demonstrating a large cystic craniopharyngioma occupying the suprasellar region and interpeduncular fossa with lateral extension into the right sylvian fissure causing symptomatic compression on the right temporal lobe, cerebral peduncle, and optic tract. There is also another component of tumor along the anterior skull base and prechiasmatic space. Near-total resection was achieved via a modified orbitozygomatic approach. **D–F:** Corresponding postoperative gadolinium-enhanced T1-weighted MR images showing minimal residual enhancement near the optic chiasm where there was adherent tumor residue.

FIG. 3. Illustrative Case 1 intraoperative photographs. **A:** Right-sided transylvian exposure of tumor (T) located lateral to the right internal carotid artery (IC) and right optic nerve (ON). **B:** More tumor (T) is identified in the prechiasmatic window with a small calcified piece (*asterisk*) adherent to the right optic nerve (ON). **C and D:** After near-total resection of the tumor, the oculomotor nerve (III) and P₂ are visualized. The basilar artery (BA) and right superior cerebellar artery (SCA) are visualized within the carotid-oculomotor window.

FIG. 4. Modified one-piece extended transbasal approach. **A:** Patient in supine position with head of bed elevated about 30° to facilitate venous drainage, and with slight neck extension to allow the frontal lobes to fall away from the skull base. **B:** Planned bicoronal incision. **C:** Harvest of vascularized pedicled pericranial flap. **D and E:** The bifrontal bone flap incorporates the anterior wall of the frontal sinus so that the lowest basal trajectory to the floor of the anterior fossa is achieved without additional removal of the supraorbital bar. The dotted line (E) shows that the exposure is flush with the contour of the anterior skull base in the coronal plane without any obstruction of line of sight. **F:** Dural opening at the frontal base with ligation and division of the superior sagittal sinus.

solved completely by the 6-week follow-up visit. Postoperative MRI showed minimal residual enhancement near the optic chiasm where there was adherent tumor residue. The patient subsequently underwent adjuvant fractionated radiation therapy without any neurological complications. This case illustrates the choice of an anterolateral transsylvian approach based upon lateral extension of the tumor.

Midline Transcranial Approaches

When accessing the lamina terminalis via an anterolateral approach, the angle of attack and surgical view into the third ventricle are oblique and the surgeon has a blind spot of the ipsilateral wall of the third ventricle. The working corridor of the lamina terminalis can be better maximized by converting to a midline transcranial approach (bifrontal transbasal approach or frontobasal interhemispheric approach).^{43,44} This offers the major advantage of direct midline orientation and access to the lamina terminalis with clear visualization and control of both walls of the third ventricle and the hypothalamus as well as the interpeduncular cistern (Figs. 4 and 5). In addition, access to the prechiasmatic space and both opticocarotid and carotid-oculomotor cisterns is readily achieved. For tumors residing in the retrochiasmatic space that extend up into the third ventricle, the lamina terminalis is opened to access and remove the tumor. Although direct visualization of the foramen of Monro is not possible, tumors extending superiorly at this level can be readily delivered through the midline trans-lamina terminalis approach. However, with a transbasal view from above, the undersurface of the optic chiasm and nerves cannot be visualized directly and

remains a blind spot for residual tumor. Blind dissection of this region can also risk injury to the perforating vessels feeding the optic apparatus.

This approach is favorable for large midline retrochiasmatic craniopharyngiomas that are situated higher on the vertical hypophyseal axis with extension up into the third ventricle, especially in cases where the working corridor between the optic chiasm and the diaphragma sellae (infrachiasmatic window) is narrow and not favorable for an EEA (Fig. 6). Although there exist several variations of midline transcranial approaches based on orbitonasal osteotomies, we favor a modified one-piece extended transbasal approach,^{43,44} described below. This involves a bifrontal craniotomy that incorporates the anterior wall of the frontal sinus so that the lowest basal trajectory to the floor of the anterior fossa is achieved without removal of the supraorbital bar as a separate osteotomy. With this approach, either a subfrontal or interhemispheric route can be used to access the lamina terminalis.

Modified One-Piece Extended Transbasal Approach: Technical Pearls and Clinical Case Correlates

The patient is positioned supine with the head elevated approximately 30° to facilitate venous drainage (Fig. 4A). The head is extended slightly to allow the frontal lobes to fall away from the skull base. Lumbar catheter drainage can be used if additional CSF drainage is anticipated for further brain relaxation. Alternatively, an external ventricular drain can also be used in cases of preexisting obstructive hydrocephalus. A bicoronal incision (Fig. 4B) is made through the galea behind the hairline with care

FIG. 5. Intraoperative photographs from illustrative Case 2 (A–D), in which a modified one-piece extended transbasal approach was used, and from a case (E and F) in which an anterolateral (supraorbital) approach was used. **A:** Subfrontal exposure optic chiasm and lamina terminalis (asterisk). **B:** Retrochiasmatic craniopharyngioma is removed via the trans-lamina terminalis corridor. **C:** Access is achievable via the lamina terminalis and prechiasmatic space. However, the blind spot is directly beneath the optic nerves and chiasm (shaded area). **D:** In a midline transbasal approach, the surgeon has control of both ependymal walls of the third ventricle and hypothalamus. **E and F:** In an anterolateral approach, such as the supraorbital approach seen here, access to the lamina terminalis (asterisk) is oblique. The major disadvantage is that the surgeon has good control and visualization of only the contralateral third ventricular wall but is blinded to the ipsilateral wall.

taken not to incise the pericranium, which is left adherent to the skull. The scalp is then elevated in a 2-layer fashion with the galeocutaneous layer elevated first followed by elevation of the vascularized pedicled pericranial flap as a separate layer (Fig. 4C). The galea is undermined posterior to the skin incision to increase the length and surface area of the pericranial flap. Care is taken to preserve the supraorbital neurovascular bundle at the supraorbital notch so as not to compromise the vascular supply to the pericranial flap. Interfascial dissection of the temporalis muscle is performed to protect the frontalis branch of the facial nerve bilaterally.

Next, a modified one-piece extended transbasal approach is performed.^{43,44} This is essentially a bifrontal bone flap that incorporates the anterior wall of the frontal sinus so that the inferior osteotomy is flush with the contour of the anterior skull base in the coronal plane (Fig. 4D and E). The midline inferior cut is at the level of the nasion, and the lateral cuts are at the level of the orbital roofs. An osteotome is used to cut the intersinus septum in the frontal sinus to disconnect the bone flap from the skull. The bone flap is then removed using a fracture technique. The frontal sinus is then exenterated, cranialized, and sealed off with betadine-soaked Gelfoam pledgets. The orbital roofs are then flattened with a high-speed drill, thereby providing a basal exposure of the anterior skull base without any bony overhang that can obstruct the line of site to the cribriform plate and the lamina terminalis. This technique obviates the need for any additional supraorbital bar removal. The dura is opened transversely along

the frontal base and the superior sagittal sinus is ligated and divided near the crista galli to avoid complications of venous infarction (Fig. 4F). The falx cerebri is then incised to the free edge to expose the interhemispheric fissure.

At this juncture, either an interhemispheric route or a subfrontal route can be chosen. For an interhemispheric route, the arachnoid of the interhemispheric fissure is divided sharply under microscopic visualization to identify the pericallosal arteries, anterior communicating artery complex, optic chiasm, lamina terminalis, olfactory tracts, and cribriform plate. Alternatively, a subfrontal exposure can be performed by elevating the right frontal lobe while avoiding retraction on the contralateral frontal lobe. It is important to dissect the arachnoid off of both olfactory tracts so that they are not avulsed from the cribriform plate during frontal lobe elevation. We also recommend placing moist Biocol collagen pledgets (Codman) over the olfactory bulbs and tracts to prevent dessication and injury during the surgery.

The lamina terminalis is identified and opened sharply (Fig. 5). Initially, the floor of the third ventricle is identified and further incised to expose tumors in the retrochiasmatic space that have elevated the floor of the third ventricle superiorly. In craniopharyngiomas that have invaded into the third ventricle or are purely intraventricular, the tumor will be visible after the lamina terminalis is opened. Intratumoral debulking with an ultrasonic aspirator may be needed in patients with large tumors to collapse the tumor. Careful extracapsular dissection is then performed by peeling the tumor off of the ependymal walls of the third

FIG. 6. Illustrative Case 2 imaging. **A–C:** Preoperative sagittal (A) and coronal (B and C) postgadolinium T1-weighted MR images demonstrating a large retrochiasmatic craniopharyngioma compressing the optic chiasm. The tumor is located above the pituitary stalk (C, *white arrow*) and extends superiorly into the third ventricle. **D and E:** Postoperative sagittal (D) and coronal (E) postgadolinium T1-weighted MR images obtained after gross-total resection via a transbasal trans-lamina terminalis approach. **F:** Sagittal T2-weighted MR image shows that the lamina terminalis corridor (*thicker white arrow*), between the optic chiasm (*white dot*) and anterior communicating artery, is larger than the infrachiasmatic corridor (*thinner white arrow*), between the optic chiasm (*white dot*) and the top of the pituitary gland.

ventricle and hypothalamus. Tumors with superior extension toward the foramen of Monro can be brought down carefully and delivered through the lamina terminalis window. As the tumor is dissected along its posteroinferior margin, the mammillary bodies are encountered and the tumor is dissected away from the membrane of Liliequist. It is best to preserve the integrity of the membrane of Liliequist since this aids in protection of the basilar artery, posterior cerebral arteries, and P₁ perforators.^{43,44}

One major disadvantage with this approach is the lack of direct visualization of the undersurface of the optic nerves and chiasm (blind spot), and therefore, one cannot perform accurate dissection of tumor adhesions in this area (Fig. 5C). Although angled endoscopes and dental mirrors may aid in visualization, blind dissection can increase the risk of injury to the optic apparatus. Moreover, the lamina terminalis can sometimes be a limited working corridor, which can result in more manipulation of the optic apparatus when dissecting larger tumors. Therefore, it is important to sequentially debulk the tumor to smaller sizes so that it can be safely delivered through the lamina terminalis corridor. Lastly, some degree of brain retraction is involved with this approach. Therefore, it is important to drain CSF from the cisterns for adequate brain relaxation.

At the time of closure, it is important to obtain a watertight dural closure as much as possible. The exposed frontal sinuses have been previously packed off with betadine-soaked Gelfoam pledgets at the time of the craniotomy (see above). Alternatively, a fat graft can be used here as well. The pericranial flap is then rotated over the obliterated

frontal sinuses to provide a vascularized barrier between the intra- and extracranial contents. The redundant distal portion of the pericranial flap is rotated over the dural closure. We do not routinely use postoperative lumbar drainage for transbasal cases.

Illustrative Case 2: Transbasal Trans-Lamina Terminalis Approach for Retrochiasmatic Craniopharyngioma

This 52-year-old man presented with progressive headaches, a 40-pound weight gain over 6 months due to an increased appetite, and bitemporal hemianopsia. MRI demonstrated a large retrochiasmatic retroinfundibular, mixed solid and cystic craniopharyngioma (Fig. 6). We initially proposed an EEA to remove the tumor because of the advantages of better visualization of the retrochiasmatic region and hypothalamus with an approach coming from below. However, after careful review of the MR images, we felt that exposure via an EEA would be limited because of the narrow infrachiasmatic operating window between the optic chiasm and the diaphragma sellae (Fig. 6F). Instead, we chose the transbasal subfrontal trans-lamina terminalis approach because of a wider and more favorable corridor between the optic chiasm and the anterior communicating artery via the lamina terminalis (Video 1).

VIDEO 1. Illustrative Case 2. Video clip showing removal of retrochiasmatic craniopharyngioma using transbasal trans-lamina terminalis approach. Copyright James K. Liu. Published with permission. Click here to view.

By approaching the tumor with a midline approach in-

FIG. 7. Illustrative Case 3. **A–C:** Preoperative coronal (A), sagittal (B), and axial (C) postgadolinium T1-weighted MR images demonstrating a giant multicystic craniopharyngioma occupying the suprasellar and anterior skull base region and also in the retrochiasmatic third ventricular region, with obstructive hydrocephalus. There is also significant interhemispheric extension with encasement of the pericallosal arteries (B, *white arrow*) and lateral extension with encasement of the left middle cerebral artery (C, *double white arrows*). A transbasal interhemispheric trans-lamina terminalis approach was performed. **D–F:** Corresponding postoperative images showing approximately 95% removal of the tumor. There was residual tumor adherent to the infrachiasmatic region, hypothalamus, and microscopic residue on portions of the pericallosal arteries.

stead of an anterolateral approach, we had control of both walls of the third ventricle and hypothalamus (Fig. 5D). The major limitation was the blind spot underneath the optic chiasm and nerves, as mentioned above. A gross-total resection was achieved, and the patient remained neurologically intact with stable vision.

Illustrative Case 3: Combined Transbasal and Endoscopic Endonasal Approach

This 19-year-old woman presented with progressive headaches, visual loss, nausea, and vomiting. MRI demonstrated a giant multicystic craniopharyngioma occupying the suprasellar and anterior skull base region, and also in the retrochiasmatic third ventricular region with obstructive hydrocephalus (Fig. 7). Because the tumor had significant interhemispheric extension with encasement of the pericallosal arteries, and also lateral extension with encasement of the left middle cerebral artery, we felt that the safest approach to resect the greatest amount of tumor with excellent vascular control was a transbasal interhemispheric approach with additional access through the lamina terminalis corridor to remove the retrochiasmatic third ventricular component.

A modified one-piece extended transbasal approach was performed. The anterior cyst in the interhemispheric fissure was carefully dissected away from the engulfed pericallosal arteries (Fig. 8). Near-total resection of the anterior cyst was achieved, leaving small microscopic remnants adherent to some portions of the pericallosal arteries. The lamina terminalis was then opened to remove the retrochiasmatic cyst. Unfortunately, the working corridor was found to be somewhat narrow. Near-total resection was achieved, leaving a small remnant adherent to the

hypothalamus and to the undersurface of the optic chiasm.

Postoperative MRI showed greater than 95% removal of the tumor with excellent decompression of the optic chiasm and resolution of hydrocephalus (Fig. 7D–F). The patient had restoration of normal vision with normal pituitary function. At 3 months after surgery, she presented with progressive headaches and worsening vision due to recurrence of the retrochiasmatic cyst with extension into the third ventricle (Fig. 9). This time, an endoscopic endonasal transplanum transtuberculum approach was performed to access the cyst in the retrochiasmatic space (Fig. 10). The endonasal corridor was noted to be wider than the lamina terminalis corridor, with better inferior-to-superior visualization of the infrachiasmatic region, hypothalamus, and third ventricle. The pituitary stalk was expanded by the tumor and not salvageable. A near-complete tumor removal was achieved, leaving a densely calcified remnant that was adherent to the undersurface of the optic chiasm. Postoperatively, the patient had restoration of normal vision and was maintained on hormone replacement therapy. She underwent additional fractionated radiation therapy to the residual adherent tumor and has remained recurrence free for 2 years.

This case illustrates the importance of having multiple operative approaches in the surgical armamentarium for craniopharyngioma treatment. The initial transbasal approach was chosen because it provided safer dissection of the engulfed pericallosal arteries and left middle cerebral artery. The diameter of the lamina terminalis working corridor is variable depending on the patient. Unfortunately, it was rather narrow in this particular patient and resulted in residual tumor that progressed with recurrence. However, this limitation was adequately addressed using an extended EEA.

FIG. 8. Illustrative Case 3 intraoperative photographs of transbasal interhemispheric trans-lamina terminalis approach. **A:** Interhemispheric dissection shows cystic tumor (T) engulfing pericallosal A₃ vessels. **B:** Tumor (T) has been carefully dissected away from the anterior communicating artery (Acom), perforators (AP), A₁, A₂, and recurrent artery of Heubner (Hb). The remaining retrochiasmatic tumor is hidden behind the lamina terminalis (T*). **C:** The lamina terminalis is opened posterior to the optic chiasm (OC) to access the tumor (T*). **D:** Final view after decompression of the optic chiasm and nerves.

Extended Transsphenoidal Approaches

While the aforementioned open surgical approaches often require some degree of brain retraction to access suprasellar craniopharyngiomas, the extended EEA via the transplanum transtuberculum corridor provides direct midline exposure to intrasellar/subdiaphragmatic, supradiaphragmatic, and retrochiasmatic craniopharyngiomas that extend up into third ventricle without any brain retraction. When performed with the traditional microscopic speculum-based technique (extended transsphenoidal approach), this transnasal approach was primarily used mainly for craniopharyngiomas of intrasellar and subdiaphragmatic origin with expanded sellas.^{13,32} However, with advances in endoscopic endonasal skull base surgery and expanded techniques, a pure EEA has gained increased acceptance for removing more extensive craniopharyngiomas associated with a normal-sized sella and suprasellar tumors of supradiaphragmatic origin.^{5,6,12,14,22,23,33,35–37,42–48} The pure EEA has a major advantage when removing retrochiasmatic craniopharyngiomas with suprasellar third ventricular extension since it provides direct visualization of the undersurface of the optic nerves, chiasm, and hypothalamus. The prior aforementioned blind spots underneath the optic chiasm encountered with an approach from above (transbasal interhemispheric or pterional/orbitozygomatic approach) can be well visualized with an EEA from below. Bimanual microdissection techniques can be performed to carefully dissect the tumor away from the optic chiasm, hypothalamus, and vascular perforators with direct visualization of the surgical plane between the tumor and critical structures.^{45,48} By avoiding blind ma-

nipulation near critical structures in the retrochiasmatic region, the pure EEA has improved our ability to avoid and minimize visual and hypothalamic complications.^{36,42} In addition, the working corridor is between the pairs of neurovascular structures (internal carotid artery, posterior communicating artery, oculomotor nerve) instead of between the nerves and arteries (optocarotid and carotid-oculomotor corridors).

The major limitations of this approach are lateral extension into the sylvian fissure and superior extension into the interhemispheric fissure. Even with the aid of angled endoscopes and instrumentation, there is limited maneuverability and inability to perform direct microvascular repair in the event of vessel injury. The higher risk of postoperative CSF leakage with the EEA was a major criticism when the approach was first introduced. However, this risk has significantly decreased to approximately 5% with the advent of multilayered reconstruction techniques using a vascularized pedicled nasoseptal flap.^{26,34} In our experience with the nasoseptal flap, our CSF leak rate has been 3.2%.⁴⁹

The endoscopic endonasal approach can also be considered for recurrent craniopharyngiomas that were previously treated via a craniotomy or prior transsphenoidal approach.^{9,14} It can also be used in combination with an open transcranial approach for extensive craniopharyngiomas occupying multiple compartments.

Purely Endoscopic Endonasal Transplanum Transtuberculum Approach: Technical Pearls and Clinical Case Correlates

The patient is positioned supine with the head slightly

FIG. 9. Illustrative Case 3 imaging. **A and B:** Postoperative sagittal and coronal postgadolinium T1-weighted MR images obtained at 3 months' follow-up showing recurrence of retrochiasmatic cystic craniopharyngioma extending into the third ventricle. An endoscopic endonasal transplanum transtuberulum approach was performed to resect the tumor. Near-total resection was achieved, leaving a calcified remnant adherent to the undersurface of the optic chiasm. **C and D:** Corresponding postoperative MR images obtained 3 months after EEA showing stable residual enhancement of microscopic tumor that was adherent to critical structures.

rotated to the right to facilitate easier access for the operating surgeon standing on the right side of the patient. A lumbar drain is placed prior to incision time for later use postoperatively. We use a 2-surgeon, 3- to 4-hand, binostril technique with a neurosurgeon and an otolaryngologist. For transplanum approaches, we prefer to use 30°-angled endoscopy because it gives the surgeon extra viewing around corners with simple rotation of the scope. The scope is placed in the 6 o'clock position in the right nostril so that the viewing angle is upwards toward the suprasellar region. The neurosurgeon can then work bimanually with the suction placed in the 12 o'clock position in the right nostril, and the working instrument (drill, dissector, microscissors, or tumor aspirator) in the left nostril.

A large vascularized pedicled nasoseptal flap is first harvested and rotated posteroinferiorly into the nasopharynx. Care is taken to protect the vascular pedicle arising from the sphenopalatine artery from inadvertent injury until the time of reconstruction. The middle and inferior turbinates are lateralized followed by a wide sphenoidotomy, posterior ethmoidectomy, and posterior septectomy of about 1.5 cm. It is critical to open the sphenoid as widely as possible, removing all sphenoid septations and bony ridges that may obstruct and hinder surgical freedom and instrument maneuverability. A high-speed diamond drill with copious irrigation is used to remove the bone from the planum sphenoidale, tuberculum sellae, and sellar dura using eggshelling technique. The shape of the bone removal at the planum sphenoidale follows the anterolateral direction of the optic nerves and will therefore appear trapezoidal. We also prefer to decompress the medial aspect of the proximal bony optic canal so that there is good control of the proximal internal carotid artery as it exits the distal dural ring in the subarachnoid space. Next, the

FIG. 10. Illustrative Case 3 intraoperative photographs obtained during second-stage EEA resection of recurrent cystic craniopharyngioma in the retrochiasmatic space. **A:** The cyst is decompressed and dissected away from the undersurface of the optic chiasm (OC). **B and C:** Tumor capsule (T) is removed from the retrochiasmatic space. **D:** After removal of the tumor, the third ventricle (3V) is visualized. Residual calcified tumor (asterisk) is densely adherent to the undersurface of the optic chiasm (OC). **E:** Endoscopic view of the third ventricle shows both foramen of Monro. **F:** Reconstruction of skull base with nasoseptal flap (NSF).

dura is opened above and below the intercavernous sinus at the level of the planum and sellar dura. The 2 incisions are then connected by coagulating and dividing the superior intercavernous sinus and diaphragma sellae to gain access to the suprasellar cistern.

The craniopharyngioma can be visualized in the retrochiasmatic space beneath the optic chiasm and between the 2 internal carotid arteries. It is critical to identify the superior hypophyseal arteries and to preserve the branches supplying the undersurface of the optic apparatus to avoid postoperative visual worsening. There is typically an arachnoid layer investing these perforators and by working between the tumor capsule and the arachnoid layer, the perforators can be safely mobilized laterally and preserved during tumor removal. For solid craniopharyngiomas, the tumor is internally debulked with a side-cutting tumor aspirator device (NICO Myriad) or ultrasonic aspirator. When decompressing cystic tumors, it is important to maintain some level of cyst turgor so that a surgical “handle” remains to facilitate extracapsular dissection from the surrounding critical neurovascular structures. We recommend using an extraarachnoid dissection technique—that is, dissecting in the plane between the tumor capsule and the tumor arachnoid, instead of between the tumor arachnoid and cisternal arachnoid.^{45,51} This keeps the laterally positioned nerves and vessels protected by both layers of arachnoid. In most cases, the membrane of Liliequist is not breached by the tumor and can act as a plane of dissection to peel the tumor safely from the basilar artery complex and P₁ perforators. In some cases, the arachnoid can be thickened and adherent due to chronic inflammation, and therefore, sharp dissection is required.

The inferior aspect of the tumor is elevated from the top of the pituitary gland to identify the base of the pituitary stalk, which is characterized by portal vessel striations. We attempt to preserve the pituitary stalk, if possible, especially if the tumor is readily dissectable off of the stalk. If, however, a gross-total resection is possible and there is tumor invading or expanding the stalk, as in Type II transinfundibular type craniopharyngiomas, we prefer to do a low stalk transection just above the pituitary gland to facilitate total removal and place the patient on postoperative hormone replacement therapy. We agree with the opinion of Dr. Oldfield⁵¹ that this strategy may be better for preventing tumor recurrence than leaving residual tumor on an anatomically intact stalk that may not always retain normal pituitary function, regardless. The tumor is generally most adherent at the level of the hypothalamus where meticulous and careful microdissection is performed. Once the tumor is free from all adherences, the tumor is then carefully delivered from the nose. Premature pulling of the tumor without complete dissection from all adherent neurovascular structures can potentially result in a catastrophic injury to a vessel or nerve.

Successful skull base reconstruction of the dural defect using a multilayered closure technique with a vascularized pedicled nasoseptal flap is critical to prevent postoperative CSF leakage. After obtaining hemostasis, a piece of Gelfoam is placed underneath the dural opening as an inlay to slow the pulsations of CSF out the dural defect. Next, a piece of autologous fascia lata is placed as an over-

lay graft over the dural opening and held in place with a monolayer of Surgicel placed over the fascia. This step is repeated again with a second layer of fascia lata. Lastly, the nasoseptal flap is then rotated into the sphenoid sinus and carefully placed over the skull base dural repair. It is important to position the flap so that direct contact is made on raw bony surfaces surrounding the skull base defect. The bony surface must be devoid of any sinus mucosa as this will increase the risk of flap dehiscence and possibly the delayed formation of mucocoeles. Another monolayer of Surgicel is placed over the edges of the flap against the surrounding bone to promote flap adherence. The flap is then bolstered with several layers of gentamicin-soaked Gelfoam pledgets followed by a Merocel expandable nasal tampon, positioned in the sphenoid sinus posterior to the nasal septum. The lumbar drain is opened temporarily during extubation to allow preferential drainage through the lumbar catheter instead of the skull base repair.

Postoperatively, the patient is maintained on antibiotics until the Merocel packing is removed in the office on postoperative Days 10–12. The lumbar drain is kept open at 5–10 ml per hour for about 72 hours after surgery. Care is taken to monitor for signs and symptoms of CSF rhinorrhea or intracranial hypotension.

Illustrative Case 4: EEA for Pediatric Retrochiasmatic Craniopharyngioma

This 12-year-old boy presented with progressive visual loss, panhypopituitarism, short stature, and obesity due to a large retrochiasmatic craniopharyngioma extending superiorly into the third ventricle (Fig. 11). After careful inspection of the preoperative MRI, it was determined by our team that the tumor would be favorable for removal via a purely endoscopic endonasal transplanum transtuberulum approach. The sphenoid sinus was generous, and the tumor presented itself to the infrachiasmatic space with a reasonable infrachiasmatic working corridor (distance between the optic chiasm and pituitary gland) (Fig. 12, Video 2).

VIDEO 2. Illustrative Case 4. Video clip showing removal of a pediatric retrochiasmatic craniopharyngioma using an endoscopic endonasal transplanum transtuberulum approach. Copyright James K. Liu. Published with permission. [Click here to view.](#)

The plane of dissection was maintained between the tumor capsule and the tumor arachnoid. We also kept the integrity of the membrane of Liliequist, which facilitated tumor dissection away from the basilar artery complex. Direct visualization of the undersurface of the optic chiasm and hypothalamus facilitated tumor dissection, which resulted in complete tumor removal. In this case, the tumor had expanded the stalk (Type II transinfundibular craniopharyngioma) so a low-stalk section was performed to release the tumor for complete removal. Postoperatively, the patient had complete restoration of vision and was maintained on hormone replacement therapy. There was no CSF leakage postoperatively, and the patient has been free of tumor recurrence for over 4 years.

Illustrative Case 5: EEA for Recurrent Cystic Craniopharyngioma

This 32-year-old woman presented with a large, cystic recurrent craniopharyngioma causing compression on her

FIG. 11. Illustrative Case 4 imaging. **A and B:** Preoperative sagittal and coronal postgadolinium T1-weighted MR images showing a pediatric retrochiasmatic craniopharyngioma compressing the optic chiasm. An EEA was performed and gross-total resection was achieved. **C and D:** Corresponding postoperative MR images showing no evidence of residual tumor with excellent decompression of the optic chiasm.

remaining functional left optic nerve. She had undergone multiple previous surgeries for a craniopharyngioma that presented during her childhood, including 3 prior frontal craniotomies and one previous microscopic transsphenoidal resection performed by another surgeon. In her prior surgeries, complete removal of the cyst wall was not achieved and only cystic drainage was performed. Her baseline preoperative examination revealed chronic blindness in the right eye and panhypopituitarism. Her preoperative MRI demonstrated a large enhancing cystic craniopharyngioma that expanded the sella (Fig. 13). We felt that the tumor presented itself to the sphenoid sinus and was, therefore, favorable for an endoscopic endonasal approach. The goal was to attempt complete removal of the cyst wall to prevent any further future recurrences and to preserve vision in her remaining left eye.

At surgery, the bony sellar floor was opened widely and the cyst wall was entered to drain the intracystic contents (Fig. 14, Video 3).

VIDEO 3. Illustrative Case 5. Video clip showing extracapsular dissection of recurrent fibrous cystic craniopharyngioma using endoscopic endonasal approach. Copyright James K. Liu. Published with permission. [Click here to view.](#)

The cyst wall was noted to be very thick and fibrous. Extracapsular removal of the cyst wall was performed by initially developing a plane of dissection between the left lateral aspect of the cyst wall and the left medial wall of the cavernous sinus. Direct visualization of the wall was facilitated with a 30°-angled endoscope. The tumor was safely dissected from the left optic nerve and chiasm. The right optic nerve was atrophic from chronic blindness and

FIG. 12. Illustrative Case 4 intraoperative photographs obtained during EEA resection of a pediatric retrochiasmatic craniopharyngioma. **A:** Endoscopic exposure of planum dura (PD), sellar dura (SD), and optic canals (OC) after removal of bone via transplanum transtuberulum corridor. **B:** Intradural resection of tumor (T) with careful dissection from the optic chiasm (OC) using a bimanual technique. **C and D:** View of retrochiasmatic space after tumor removal including third ventricle (3V), hypothalamus (H), and mammillary bodies (M). **E:** View of skull base dural defect with both frontal lobes (F) exposed. **F:** Skull base reconstruction with nasoseptal flap (NSF) and preservation of its vascular pedicle (VP).

FIG. 13. Illustrative Case 5 imaging. **A–C:** Preoperative sagittal (A), coronal (B), and axial (C) postgadolinium T1-weighted MR images showing a recurrent cystic craniopharyngioma. Near-complete extracapsular resection of fibrous cyst wall was achieved via EEA. Small microscopic remnant was adherent to right cavernous sinus wall. **D–F:** Corresponding postoperative MR images obtained at 3 months' follow-up showing no gross recurrent or residual tumor.

not readily identifiable. The remainder of the cyst wall was debulked with a side-cutting tumor aspirator. A near-total resection was achieved, leaving a microscopic remnant adherent to the right medial wall of the cavernous sinus. Postoperatively, the patient had normal vision in the left eye and no CSF leakage. She underwent fractionated radiation therapy to the right cavernous sinus and has not had any further recurrences at 3 years' follow-up. This case illustrates the importance of complete cyst wall removal and the usefulness of the EEA for recurrent tumors despite prior multiple craniotomies and transnasal procedures.

Intraventricular Approaches

The intraventricular approaches to craniopharyngiomas involving the lateral and third ventricles typically include the transcallosal and transcortical transventricular approaches. These approaches can be performed with minimal brain retraction and are excellent options for intraventricular tumors that extend into the anterior third ventricle and lateral ventricle. In cases in which the lateral ventricles are enlarged due to hydrocephalus or if the tumor presents itself to one lateral ventricle, the transcortical approach can be considered.

Alternatively, we prefer the interhemispheric transcallosal approach because it provides excellent midline access to both lateral ventricles and third ventricle without transgressing the cerebral cortex, thereby decreasing the risk of seizures. It also does not rely on large lateral ventricles to create the surgical corridor. However, these approaches are not useful for obtaining access and direct visual control of the suprasellar region, and can carry the risk of memory loss (forniceal injury), arterial stroke

(injury to pericallosal arteries in transcallosal approach), venous infarct (injury to internal cerebral veins or bridging veins in transcallosal approach), and postoperative seizures (transcortical approach).

In summary, the intraventricular approaches can be used alone for purely intraventricular craniopharyngiomas, or they can be used in combination with other anterolateral and midline transcranial approaches to resect the intra- and extraventricular portions of the tumor.^{11,46} The trans-lamina terminalis approach for third ventricular craniopharyngiomas has been discussed in the previous section on the transbasal approach, and will not be discussed here.

Transcortical Transventricular Approach: Technical Pearls

When performing the transcortical transventricular approach, the patient is positioned supine with the head elevated approximately 30° to facilitate venous drainage. A unilateral frontal craniotomy is performed on the side of the tumor extension or on the side of the surgeon's dominant hand. A ventricular catheter is placed into the lateral ventricle under stereotactic guidance and a small corticectomy is made at the catheter site. Under microscopic visualization, the catheter tract is followed and expanded until the lateral ventricle is exposed. At this point, it is essential to identify the choroid plexus, foramen of Monro, septum pellucidum, and thalamostriate vein to establish surgical orientation. Further access to the third ventricle can be performed using a subchoroidal approach, or in some cases, a transforaminal approach if the foramen of Monro is dilated.¹¹ One disadvantage is the oblique viewing angle to the third ventricle that prevents the surgeon from ad-

FIG. 14. Illustrative Case 5 intraoperative photographs obtained during EEA resection of a recurrent cystic craniopharyngioma. This patient had undergone multiple prior craniotomies and transsphenoidal resection and had vision remaining only in the left eye. **A:** Endoscopic transsphenoidal transsellar exposure of cyst wall (CW). **B:** Thick and fibrous cyst wall (CW) was fenestrated widely to drain cystic contents. **C–E:** Extracapsular dissection of cyst wall (CW) away from the left optic nerve (ON) and both walls of the cavernous sinus. **F:** Final view after near-complete removal of cyst wall. Small microscopic remnant was adherent to the right cavernous sinus wall. The right optic nerve was atrophic and not visible because the patient was chronically blind in the right eye.

equately visualizing the ipsilateral wall of the third ventricle.

Interhemispheric Transcallosal Approach: Technical Pearls

The transcallosal approach, on the other hand, offers midline access so that both walls of the third ventricle are identified. The patient is positioned supine in the same manner and a unilateral frontal craniotomy is performed with extension of the bone flap across the midline. This allows mild retraction of the superior sagittal sinus when reflecting the dura medially to facilitate adequate access and visualization of the interhemispheric fissure. We prefer to position the patient in the lateral position so that the dependent ipsilateral frontal lobe falls away from the falx to facilitate gravity-assisted retractorless access to the interhemispheric fissure. The head of bed is elevated and the neck is flexed laterally so that the falx cerebri is roughly 30° from the horizontal plane. This provides a comfortable viewing trajectory to the interhemispheric fissure for the surgeon. In our experience, the arachnoid membranes over the interhemispheric fissure are very easy to dissect with gravity assistance in this lateral position. The pericallosal arteries are identified and separated to create a safe working corridor to the corpus callosum between the 2 vessels. After confirmation of the desired callosotomy tar-

get and working trajectory with image guidance, the corpus callosum is divided approximately 2–2.5 cm to access the lateral ventricle. Fenestration and partial resection of the septum pellucidum allows access to both lateral ventricles. For access to the third ventricle, an interforaminal approach can be performed when using the transcallosal approach. This can be performed by dividing the velum interpositum and working in between both fornices and internal cerebral veins. The fornices can be carefully separated by spreading the tips of the bipolar forceps or microbayonnetted forceps (bipolar spread technique). The arachnoid of the tela choroidea is identified and divided to drop into the third ventricle. This allows excellent midline visualization and control of both walls of the third ventricle. Alternatively, a subchoroidal or transforaminal corridor can be chosen as well to access the third ventricle. The most anterior portion of the third ventricle, including the supraoptic recess, remains a difficult area to visualize with the transcallosal interforaminal approach. One must use extreme caution not to cause inadvertent trauma to the fornices with microinstrumentation and suction devices.

Lateral Transcranial Approaches

Lateral approaches to craniopharyngiomas include the transpetrosal approach and the subtemporal approach.^{1,2,27,38}

The transpetrosal (posterior petrosal) approach to retrochiasmatic craniopharyngiomas was originally advocated by Hakuba et al.²⁷ and further popularized by Al-Mefty et al.^{1,2} and Kunihiro et al.³⁸ The transpetrosal approach offers a less commonly used, but accepted, alternative avenue to the retrochiasmatic region coming from a posterior-to-anterior and inferior-to-superior viewing projection to the inferior and posterior surfaces of the chiasm, floor of the third ventricle, and the hypothalamus. Some potential advantages include the working trajectory and access to the retrosellar and retroclival region for retroinfundibular craniopharyngiomas. This approach allows the surgeon to access the tumor behind the stalk without having to mobilize or transpose the pituitary stalk and gland (pituitary transposition) as used in the EEA. The disadvantages of this approach are prolonged temporal lobe retraction, the risk of venous infarct from potential injury to the vein of Labbé or from ligation of the superior petrosal sinus, prolonged operative time due to temporal bone drilling, and technical difficulty in performing a mastoidectomy in young children with a nonpneumatized mastoid sinus. The other major disadvantage is the narrow surgical corridors between the nerves (e.g., oculomotor nerve) and small perforating vessels (posterior communicating artery and perforators). Although division of the posterior communicating artery can be performed to widen the corridor,³⁸ this maneuver can certainly carry some risk of ischemic injury. Nevertheless, this represents another potential skull base approach in the armamentarium for the surgical removal of retrochiasmatic craniopharyngiomas.

The subtemporal approach is another variation of the lateral corridor that does not require extensive petrosectomy and mastoid bone drilling and can be performed with a smaller linear or curvilinear incision and relatively smaller bony opening.⁵⁸ Therefore, the operative time for the surgical exposure is reduced and the potential complications for CSF leakage may be lower by avoiding entrance into a pneumatized temporal bone. However, the smaller working corridor increases the need for more temporal lobe retraction and can limit the surgical freedom and angles of attack when compared with a transpetrosal approach. The lack of complete transtentorial division also eliminates the advantage of the lateral inferior-to-superior viewing trajectory to the retrochiasmatic space that is inherent to the transpetrosal approach. Due to these limitations, the potential for achieving a gross-total resection is less feasible.⁵⁸

Transpetrosal Approach: Technical Pearls

The patient is positioned supine with the head turned to the contralateral side approximately 60°. A lumbar drain is placed prior to surgery to facilitate intraoperative CSF drainage for temporal lobe relaxation. A large retroauricular C-shaped incision is made approximately 3 finger breadths behind the pinna, curving anteriorly to the frontal region just behind the hairline. Alternatively, a hybrid pre- and postauricular incision can be made as well. After reflection of a galeocutaneous skin flap, a temporal fascial-pericranial flap that is pedicled posteriorly at the sternocleidomastoid muscle is raised and used at the time of closure for skull base reconstruction. The degree of

petrosectomy is tailored to the patient's pathology and preoperative hearing status. A retrolabyrinthine mastoidectomy is performed in patients who have intact and serviceable hearing function. If additional exposure is needed, a partial labyrinthectomy petrous apicectomy (transcrural approach) can be performed by drilling off the superior and posterior semicircular canals with sequential sealing off of the openings of the membranous canals, which can preserve hearing in some cases.^{30,55} If preoperative hearing is nonserviceable, a translabyrinthine approach can be performed, providing wider exposure to the petrous apex. If needed, an anterior petrosectomy (Kawase's approach) can also be added to the exposure, depending on the size and extent of the tumor. More recently, Kunihiro et al.³⁸ have described a more limited retrolabyrinthine petrosectomy where only enough petrous bone is exposed to allow ligation and division of the superior petrosal sinus.

After the mastoidectomy and petrosectomy are performed, an L-shaped temporo-occipito-suboccipital craniotomy is performed to expose the temporal lobe dura, retrosigmoid dura, and transverse and sigmoid sinuses. It is important to expose enough bone over the retrosigmoid dura so that the sigmoid sinus can be mobilized posteriorly to open up the presigmoid surgical corridor, particularly in patients with anterior-riding sigmoid sinuses.

The presigmoid dura is opened along the anterior margin of the sigmoid sinus, and the temporal lobe dura is opened horizontally along the temporal base. The superior petrosal sinus is ligated and divided anteriorly to the drainage point of the superior petrosal vein. The tentorium is then incised toward the tentorial incisura behind the entrance of the trochlear nerve. It is critical to avoid injury to the vein(s) of Labbé and the trochlear nerve during splitting of the tentorium. The tentorium can also be excised by making another cut anteriorly at the level of the porus trigeminus.³⁹

The temporal lobe is retracted superiorly and the sigmoid sinus and cerebellum are retracted posteriorly to create the surgical corridor to the retrochiasmatic space. The oculomotor nerve, trochlear nerve, trigeminal nerve, optic tract, internal carotid artery, posterior communicating artery and associated perforating vessels, and posterior cerebral artery are identified. The tumor is exposed behind the optic chiasm, under the hypothalamus in the interpeduncular cistern. The working corridors are mainly between the oculomotor nerve and the posterior communicating artery and perforators and between the oculomotor nerve and the trochlear nerve.^{38,52}

The dural defect is closed primarily and augmented with dural grafts as needed. The temporal fascial pericranial flap is rotated to cover the dural repair to prevent CSF leakage. Abdominal fat is used to fill the dead space in the mastoidectomy and petrosectomy defect. Care is taken not to overpack the fat so as to avoid mass effect on the temporal lobe. The lumbar drain is kept open at 5–10 ml per hour postoperatively for about 3–5 days to prevent postoperative CSF leakage.

Subtemporal Approach: Technical Pearls

The patient is positioned supine with the head turned with a gel roll underneath the ipsilateral shoulder. Alterna-

tively, if the patient has limited neck mobility, he or she is placed in the lateral position. The key is to have the head positioned completely lateral so that the temporal surface is parallel to the floor. Lumbar catheter drainage should be performed intraoperatively to facilitate brain relaxation for subtemporal retraction.

We prefer a larger skin incision and craniotomy for the subtemporal approach so that there are more angles of surgical freedom in a wider working corridor. A preauricular curvilinear incision is made behind the hairline and the temporalis muscle is mobilized anteriorly. A temporal craniotomy is performed roughly 50% anterior and 50% posterior to the root of the zygoma. The floor of the middle fossa is drilled down extradurally so that there is flat trajectory along the cranial base without obstruction of line of sight. The dura is opened in a horseshoe fashion and reflected toward the temporal base.

After adequate brain relaxation is achieved with lumbar drainage, the temporal lobe is retracted to provide a subtemporal working corridor to the tentorial incisura. The trochlear nerve is identified in the ambient cistern where it enters the tentorium. Either a tentorial stitch placed posterior to the entrance of the trochlear nerve or a tentorial incision can be used to expand the deeper working corridor. The tumor is accessed between the tentorial incisura and oculomotor nerve and between the oculomotor nerve and posterior communicating artery. Care is taken to preserve the small perforators coming off the posterior communicating artery.

This approach has major disadvantages due to the need for temporal lobe retraction that provides a deep, narrow working corridor between critical arteries and nerves. In our opinion, visualization of the perforators to the optic chiasm is poor. The surgeon also has poor visualization of the critical structures on the contralateral side. Thus, the chance for safe gross-total resection is significantly reduced. In a recent series of 5 cases in which a subtemporal approach was used, gross-total resection was not achieved in any of the cases, and temporal lobe edema was seen on postoperative FLAIR images in 80% of the patients.⁵⁸

Conclusions

There are a variety of microsurgical and endoscopic approaches that can be applied to craniopharyngiomas. The major surgical approaches to craniopharyngiomas can be summarized into 5 major categories: anterolateral transcranial, midline transcranial, extended endoscopic endonasal, intraventricular, and lateral transcranial. While each approach has its advantages and limitations, a personalized approach tailored to the individual patient based on multiple factors is crucial in determining the optimal treatment strategy. Knowledge and expertise in both traditional microsurgical and endoscopic endonasal techniques are necessary for the surgical armamentarium for craniopharyngioma management.

References

1. Al-Mefty O, Ayoubi S, Kadri PA: The petrosal approach for the resection of retrochiasmatic craniopharyngiomas. *Neurosurgery* **62** (5 Suppl 2):ONS331–ONS336, 2008
2. Al-Mefty O, Ayoubi S, Kadri PA: The petrosal approach for the total removal of giant retrochiasmatic craniopharyngiomas in children. *J Neurosurg* **106** (2 Suppl):87–92, 2007
3. Aziz KM, Froelich SC, Cohen PL, Sanan A, Keller JT, van Loveren HR: The one-piece orbitozygomatic approach: the MacCarty burr hole and the inferior orbital fissure as keys to technique and application. *Acta Neurochir (Wien)* **144**:15–24, 2002
4. Bunin GR, Surawicz TS, Witman PA, Preston-Martin S, Davis F, Bruner JM: The descriptive epidemiology of craniopharyngioma. *J Neurosurg* **89**:547–551, 1998
5. Cappabianca P, Cavallo LM: The evolving role of the transsphenoidal route in the management of craniopharyngiomas. *World Neurosurg* **77**:273–274, 2012
6. Cappabianca P, Cavallo LM, Solari D, Esposito F: Comments on: hypothalamus-referenced classification for craniopharyngiomas: evidence provided by the endoscopic endonasal approach. *Neurosurg Rev* **36**:340, 2013
7. Cavallo LM, Cappabianca P: Craniopharyngiomas: infradiaphragmatic and supradiaphragmatic type and their management in modern times. *World Neurosurg* **81**:683–684, 2014
8. Cavallo LM, Frank G, Cappabianca P, Solari D, Mazzatenta D, Villa A, et al: The endoscopic endonasal approach for the management of craniopharyngiomas: a series of 103 patients. *J Neurosurg* **121**:100–113, 2014
9. Cavallo LM, Prevedello DM, Solari D, Gardner PA, Esposito F, Snyderman CH, et al: Extended endoscopic endonasal transsphenoidal approach for residual or recurrent craniopharyngiomas. *J Neurosurg* **111**:578–589, 2009
10. Cavallo LM, Solari D, Esposito F, Villa A, Minniti G, Cappabianca P: The role of the endoscopic endonasal route in the management of craniopharyngiomas. *World Neurosurg* **82** (6 Suppl):S32–S40, 2014
11. Chamoun R, Couldwell WT: Transcortical-transforaminal microscopic approach for purely intraventricular craniopharyngioma. *Neurosurg Focus* **34** (1 Suppl):Video 4, 2013
12. Conger AR, Lucas J, Zada G, Schwartz TH, Cohen-Gadol AA: Endoscopic extended transsphenoidal resection of craniopharyngiomas: nuances of neurosurgical technique. *Neurosurg Focus* **37**(4):E10, 2014
13. Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T: Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. *Neurosurgery* **55**:539–550, 2004
14. Dhandapani S, Singh H, Negm HM, Cohen S, Souweidane MM, Greenfield JP, et al: Endonasal endoscopic reoperation for residual or recurrent craniopharyngiomas. *J Neurosurg* [epub ahead of print May 6, 2016. DOI: 10.3171/2016.1.JNS152238]
15. Ditzel Filho LF, McLaughlin N, Bresson D, Solari D, Kassam AB, Kelly DF: Supraorbital eyebrow craniotomy for removal of intraaxial frontal brain tumors: a technical note. *World Neurosurg* **81**:348–356, 2014
16. Elliott RE, Hsieh K, Hochm T, Belitskaya-Levy I, Wisoff J, Wisoff JH: Efficacy and safety of radical resection of primary and recurrent craniopharyngiomas in 86 children. *J Neurosurg Pediatr* **5**:30–48, 2010
17. Elliott RE, Wisoff JH: Successful surgical treatment of craniopharyngioma in very young children. *J Neurosurg Pediatr* **3**:397–406, 2009
18. Elliott RE, Wisoff JH: Surgical management of giant pediatric craniopharyngiomas. *J Neurosurg Pediatr* **6**:403–416, 2010
19. Fahlbusch R, Hofmann BM: Surgical management of giant craniopharyngiomas. *Acta Neurochir (Wien)* **150**:1213–1226, 2008

20. Fahlbusch R, Honegger J, Paulus W, Huk W, Buchfelder M: Surgical treatment of craniopharyngiomas: experience with 168 patients. **J Neurosurg** 90:237–250, 1999
21. Fatemi N, Dusick JR, de Paiva Neto MA, Malkasian D, Kelly DF: Endonasal versus supraorbital keyhole removal of craniopharyngiomas and tuberculum sellae meningiomas. **Neurosurgery** 64 (5 Suppl 2):269–286, 2009
22. Gardner PA, Kassam AB, Snyderman CH, Carrau RL, Mintz AH, Grahovac S, et al: Outcomes following endoscopic, expanded endonasal resection of suprasellar craniopharyngiomas: a case series. **J Neurosurg** 109:6–16, 2008
23. Gardner PA, Prevedello DM, Kassam AB, Snyderman CH, Carrau RL, Mintz AH: The evolution of the endonasal approach for craniopharyngiomas. **J Neurosurg** 108:1043–1047, 2008
24. Gerganov V, Metwali H, Samii A, Fahlbusch R, Samii M: Microsurgical resection of extensive craniopharyngiomas using a frontolateral approach: operative technique and outcome. **J Neurosurg** 120:559–570, 2014
25. Golshani KJ, Lalwani K, Delashaw JB, Selden NR: Modified orbitozygomatic craniotomy for craniopharyngioma resection in children. **J Neurosurg Pediatr** 4:345–352, 2009
26. Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, et al: A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. **Laryngoscope** 116:1882–1886, 2006
27. Hakuba A, Nishimura S, Inoue Y: Transpetrosal-transientorial approach and its application in the therapy of retrochiasmatic craniopharyngiomas. **Surg Neurol** 24:405–415, 1985
28. Hoffman HJ, De Silva M, Humphreys RP, Drake JM, Smith ML, Blaser SI: Aggressive surgical management of craniopharyngiomas in children. **J Neurosurg** 76:47–52, 1992
29. Honegger J, Buchfelder M, Fahlbusch R, Däubler B, Dörr HG: Transsphenoidal microsurgery for craniopharyngioma. **Surg Neurol** 37:189–196, 1992
30. Horgan MA, Delashaw JB, Schwartz MS, Kellogg JX, Spektor S, McMenomey SO: Transcrural approach to the petroclival region with hearing preservation. Technical note and illustrative cases. **J Neurosurg** 94:660–666, 2001
31. Jane JA Jr, Kiehna E, Payne SC, Early SV, Laws ER Jr: Early outcomes of endoscopic transsphenoidal surgery for adult craniopharyngiomas. **Neurosurg Focus** 28(4):E9, 2010
32. Jane JA Jr, Prevedello DM, Alden TD, Laws ER Jr: The transsphenoidal resection of pediatric craniopharyngiomas: a case series. **J Neurosurg Pediatr** 5:49–60, 2010
33. Kassam AB, Gardner PA, Snyderman CH, Carrau RL, Mintz AH, Prevedello DM: Expanded endonasal approach, a fully endoscopic transnasal approach for the resection of midline suprasellar craniopharyngiomas: a new classification based on the infundibulum. **J Neurosurg** 108:715–728, 2008
34. Kassam AB, Thomas A, Carrau RL, Snyderman CH, Vescan A, Prevedello D, et al: Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. **Neurosurgery** 63 (1 Suppl 1):ONS44–ONS53, 2008
35. Kenning TJ, Beahm DD, Farrell CJ, Schaberg MR, Rosen MR, Evans JJ: Endoscopic endonasal craniopharyngioma resection. **Neurosurg Focus** 32 (1 Suppl):Video 5, 2012
36. Komotar RJ, Starke RM, Raper DM, Anand VK, Schwartz TH: Endoscopic endonasal compared with microscopic transsphenoidal and open transcranial resection of craniopharyngiomas. **World Neurosurg** 77:329–341, 2012
37. Koutourousiou M, Gardner PA, Fernandez-Miranda JC, Tyler-Kabara EC, Wang EW, Snyderman CH: Endoscopic endonasal surgery for craniopharyngiomas: surgical outcome in 64 patients. **J Neurosurg** 119:1194–1207, 2013
38. Kunihiro N, Goto T, Ishibashi K, Ohata K: Surgical outcomes of the minimum anterior and posterior combined transpetrosal approach for resection of retrochiasmatic craniopharyngiomas with complicated conditions. **J Neurosurg** 120:1–11, 2014
39. Kusumi M, Fukushima T, Mehta AI, Aliabadi H, Nonaka Y, Friedman AH, et al: Tentorial detachment technique in the combined petrosal approach for petroclival meningiomas. **J Neurosurg** 116:566–573, 2012
40. Laws ER Jr: Transsphenoidal microsurgery in the management of craniopharyngioma. **J Neurosurg** 52:661–666, 1980
41. Laws ER Jr: Transsphenoidal removal of craniopharyngioma. **Pediatr Neurosurg** 21 (Suppl 1):57–63, 1994
42. Leng LZ, Greenfield JP, Souweidane MM, Anand VK, Schwartz TH: Endoscopic, endonasal resection of craniopharyngiomas: analysis of outcome including extent of resection, cerebrospinal fluid leak, return to preoperative productivity, and body mass index. **Neurosurgery** 70:110–124, 2012
43. Liu JK: Modified one-piece extended transbasal approach for translamina terminalis resection of retrochiasmatic third ventricular craniopharyngioma. **Neurosurg Focus** 34 (1 Suppl):Video 1, 2013
44. Liu JK, Christiano LD, Gupta G, Carmel PW: Surgical nuances for removal of retrochiasmatic craniopharyngiomas via the transbasal subfrontal translamina terminalis approach. **Neurosurg Focus** 28(4):E6, 2010
45. Liu JK, Christiano LD, Patel SK, Eloy JA: Surgical nuances for removal of retrochiasmatic craniopharyngioma via the endoscopic endonasal extended transsphenoidal transplanum transtuberculum approach. **Neurosurg Focus** 30(4):E14, 2011
46. Liu JK, Cole CD, Kestle JR, Brockmeyer DL, Walker ML: Cranial base strategies for resection of craniopharyngioma in children. **Neurosurg Focus** 18(6A):E9, 2005
47. Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT: The history and evolution of transsphenoidal surgery. **J Neurosurg** 95:1083–1096, 2001
48. Liu JK, Eloy JA: Endoscopic endonasal transplanum transtuberculum approach for resection of retrochiasmatic craniopharyngioma. **Neurosurg Focus** 32 (1 Suppl):Video 2, 2012
49. Liu JK, Schmidt RF, Choudhry OJ, Shukla PA, Eloy JA: Surgical nuances for nasoseptal flap reconstruction of cranial base defects with high-flow cerebrospinal fluid leaks after endoscopic skull base surgery. **Neurosurg Focus** 32(6):E7, 2012
50. McLaughlin N, Ditzel Filho LF, Shahlaie K, Solari D, Kassam AB, Kelly DF: The supraorbital approach for recurrent or residual suprasellar tumors. **Minim Invasive Neurosurg** 54:155–161, 2011
51. Oldfield EH: Editorial. Transnasal endoscopic surgery for craniopharyngiomas. **Neurosurg Focus** 28(4):E8a, 2010
52. Oyama K, Prevedello DM, Ditzel Filho LF, Muto J, Gun R, Kerr EE, et al: Anatomic comparison of the endonasal and transpetrosal approaches for interpeduncular fossa access. **Neurosurg** 37(4):E12, 2014
53. Pascual JM, González-Llanos F, Barrios L, Roda JM: Intraventricular craniopharyngiomas: topographical classification and surgical approach selection based on an extensive overview. **Acta Neurochir (Wien)** 146:785–802, 2004
54. Samii M, Tatagiba M: Surgical management of craniopharyngiomas: a review. **Neurol Med Chir (Tokyo)** 37:141–149, 1997
55. Sekhar LN, Schessel DA, Bucur SD, Raso JL, Wright DC: Partial labyrinthectomy petrous apicectomy approach to neoplastic and vascular lesions of the petroclival area. **Neurosurgery** 44:537–552, 1999

56. Van Effenterre R, Boch AL: Craniopharyngioma in adults and children: a study of 122 surgical cases. **J Neurosurg** **97**:3–11, 2002
57. Wilson DA, Duong H, Teo C, Kelly DF: The supraorbital endoscopic approach for tumors. **World Neurosurg** **82** (6 Suppl):S72–S80, 2014
58. Wong RH, De Los Reyes K, Alikhani P, Sivaknathan S, van Gompel J, van Loveren H, et al: The subtemporal approach to retroinfundibular craniopharyngiomas: a new look at an old approach. **Neurosurgery** [epub ahead of print], 2015
59. Yaşargil MG, Curcic M, Kis M, Siegenthaler G, Teddy PJ, Roth P: Total removal of craniopharyngiomas. Approaches and long-term results in 144 patients. **J Neurosurg** **73**:3–11, 1990

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Liu. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Liu, Sevak. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Liu. Study supervision: Liu.

Supplemental Information

Videos

Video 1. <https://vimeo.com/185325909>.

Video 2. <https://vimeo.com/185326069>.

Video 3. <https://vimeo.com/185326164>.

Video abstract. <https://vimeo.com/191005140>.

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