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Endoscopic transsphenoidal pituitary surgery in children ☆

Edward C. Kuan, MD, MBA[a], Phillip B. Storm, MD[b], James N. Palmer, MD[a], Nithin D. Adappa, MD[a]

From the [a]Department of Otorhinolaryngology—Head and Neck Surgery, University of Pennsylvania, Philadephia, Pennsylvania
[b]Division of Pediatric Neurosurgery, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

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With increasing adoption of endoscopic techniques and improved knowledge of skull base anatomy and approaches, transsphenoidal pituitary surgery is now being performed on patients of all ages. Surgical principles are similar between pediatric and adult patients, but there are special considerations for the pediatric population in terms of instrumentation, surgical anatomy, and postoperative care. Wide exposure to the sella, oftentimes to accommodate multiple instruments and the endoscope, is frequently necessary. Persistent collaboration among the otolaryngology, neurosurgery, and anesthesiology teams is of critical importance to ensure optimal outcomes.

Introduction

Tumors of the pituitary gland are generally quite rare among pediatric patients (defined as age 18 and younger), with 1 early series reporting that they account for approximately 15% of all pituitary tumors.[1] Initially, it was thought that these tumors were more aggressive or invasive than adult pituitary tumors, but, with increased experience in surgical management of these tumors, that philosophy has since changed.[2,3] There also appears to be a preponderance toward functional adenomas.[4] Patients with prolactinomas tend to require predominantly medical therapy for either cure or normalization of serum prolactinoma, while surgical therapy, though potentially curative as well, generally plays a more adjunctive role (eg, decompression of cystic degeneration).[5-7]

Traditionally, pituitary neoplasms were approached via an open transcranial or microscopic sublabial or transnasal approach. With increasing proficiency and adoption of endoscopic techniques, as well as improved instrumentation, endoscopic endonasal approaches have gained in favor across many skull base centers across the world. The management of patients with skull base lesions revolves around a multidisciplinary panel of specialists, including neurosurgeons, otolaryngologists, endocrinologists, radiation oncologists, intensivists, and anesthesiologists, to name a few. There is already a wealth of evidence suggesting the safety and efficacy of treating pituitary tumors endoscopically in adults. However, only recently have the same techniques and principles been applied to treating the pediatric population, with many tertiary care pediatric centers beginning to present and report on their experiences. Moreover, due

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Address reprint requests and correspondence: Nithin D. Adappa, MD, Department of Otorhinolaryngology—Head & Neck Surgery, University of Pennsylvania, 3400 Spruce Street, Ravdin 5, Philadelphia, PA 19104.

E-mail address: nithin.adappa@uphs.upenn.edu

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to the naturally smaller corridor afforded by the pediatric nose, technical modifications and nuances need to be accounted for when treating these patients. We provide an overview of our institution's technique, surgical principles, and care pathways in the management of pediatric patients with surgically treatable pituitary tumors.

Setup

Prior to surgery, a highresolution computed tomography (CT) scan with thin axial cuts is useful for review of surgical anatomy of the nasal passages. There will almost always be a series of magnetic resonance imaging (MRI) centered over the pituitary region, and this would also be helpful to review to better delineate the surrounding soft tissue and neurovascular structures, most notably the optic chiasm, cavernous sinus, and carotid arteries.

The patient is brought into the operating room and placed under general endotracheal anesthesia. The endotracheal tube is taped to the left lower lip to facilitate dissection while standing on the right side of the patient. If not already done so, the patient should be repositioned such that the top of the head is all the way to the superior edge of the operating room table. The eyes are taped with silk tape and will be left exposed within the surgical field. Size-appropriate cottonoid pledgets moistened, but not soaked, with oxymetazoline (Afrin) solution should be placed into the bilateral nasal passages as early as possible and left in place until the surgical team is ready to instrument the nose. This provides adequate decongestion and preemptive hemostasis of the nasal mucosa and improves the surgical field, and is especially important as many children have a history of allergic rhinitis, which engorges the nasal and turbinate mucosa. Pediatric patients who undergo pituitary dissection are at risk for transient postoperative diabetes insipidus, and thus the anesthesia team may elect to place a central venous catheter, arterial line, and Foley catheter for hemodynamic and fluid monitoring. We do not routinely place lumbar drains for cerebrospinal fluid (CSF) diversion, and, in accordance with the current literature, have not noticed an adverse effect on postoperative CSF leak outcomes.[8-10]

Once monitors have been placed, the operating room table is turned 180 degrees away from the anesthesia machine, with special care to purposely increase slack on the airway circuit to prevent inadvertent airway loss during dissection. As we utilize a 3- or 4-hand, 2-surgeon approach, both arms are tucked securely to allow for adequate standing room on both the left and right sides of the patient. The table is dropped as low as possible, followed by gradual placement of the patient in reverse Trendelenburg position to elevate the head of bed, which has been shown to improve the surgical field.[11,12] We utilize a warming blanket to cover the patient below the chest. If there is concern for a large, high-flow intraoperative CSF leak (uncommon with pituitary tumors), then the warming blanket is taped away from the right lower quadrant of the abdomen and/or the right lateral thigh so that these areas may be prepped with povidone-iodine and draped in a sterile fashion in anticipation for autograft harvest.

At this point, the image guidance system may be calibrated and registered for use. Following this, draping of the patient with care to expose the eyes and nose are completed, and the surgeon and ancillary staff both in and out of the surgical field prepares instrumentation required for the surgery.

Operative technique

Approach

Depending on the size of the patient, the surgeon may need to begin the dissection with a smaller caliber nasal endoscope (ie, 2.4 mm diameter). Initially, both nasal cavities are inspected with the endoscope to determine which side would better accommodate neurosurgical dissecting instruments. Conventionally, we favor performing most of the dissection on the right side, which favors right-handed neurosurgeons operating on the patient's right through the patient's right nares and the rhinologist holding the endoscope on the patient's left through the patient's left nares. A major challenging of endoscopic skull base surgery in pediatric patients is the naturally smaller anatomic confines of the nose, especially if the primary tumor and/or anticipated skull base defect is large. For this reason, we often consider bilateral maxillary antrostomies and ethmoidectomies to provide more superior and lateral room for multiple instruments to work in an otherwise already cramped anatomic area. We typically do not open up additional sinuses in adult populations but find it does help improve our working space in pediatric cases.

A small volume (1 mL or less) of local anesthesia may be infiltrated in the form of 1% lidocaine with 1:100,000 epinephrine to the axilla and anterior head of the middle turbinate. It is important to communicate with the anesthesia staff when local anesthesia is delivered, as hemodynamic variables may change during this process, especially in younger children. Though there is some evidence supporting the use of dilute topical epinephrine (1:1,000 or 1:2,000) for intraoperative hemostasis in pediatric patients, we favor minimizing any changes in hemodynamic variables and exclusively use topical oxymetazoline and thrombin (once dura is exposed) for hemostasis.[13] In younger children, the adenoid pad is often still rather hypertrophic and decreases the potential drip space, so topical hemostasis plays an even more important role in optimizing visualization.

We do not routinely raise a nasoseptal flap for sellar reconstruction upfront; rather, we utilize the "rescue flap" technique and only raise the flap if an intraoperative CSF leak is encountered.[14] Nuances and technical aspects of nasoseptal flap harvest and placement will be covered in a separate section of this book.

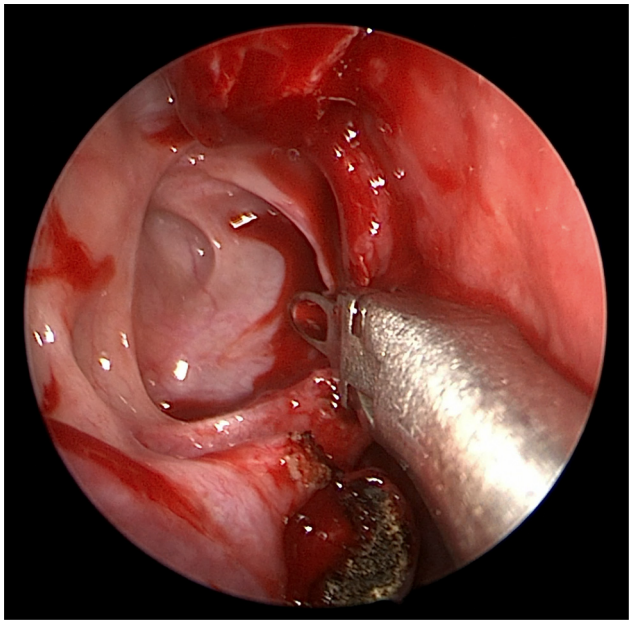

Figure 1 Following resection of the middle turbinate, the superior turbinate is identified and the inferior one-third of this structure is transected with a straight-through-cutting forceps, leading to the natural ostium of the sphenoid sinus.

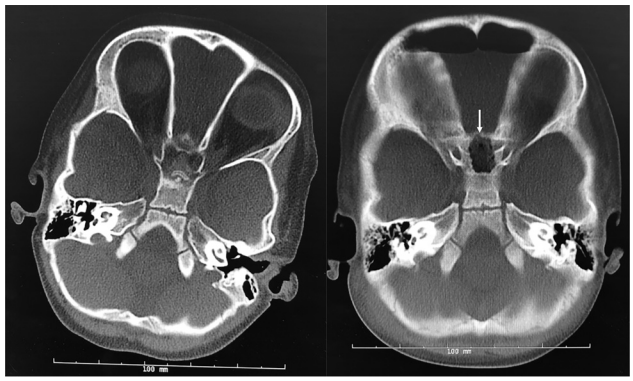

Figure 2 Conchal sphenoid pneumatization pattern (left) requiring drilling for access to the sella, tuberculum, and planum. Postoperatively, there is expected pneumocephalus and a sphenoid neosinus (right, white arrow).

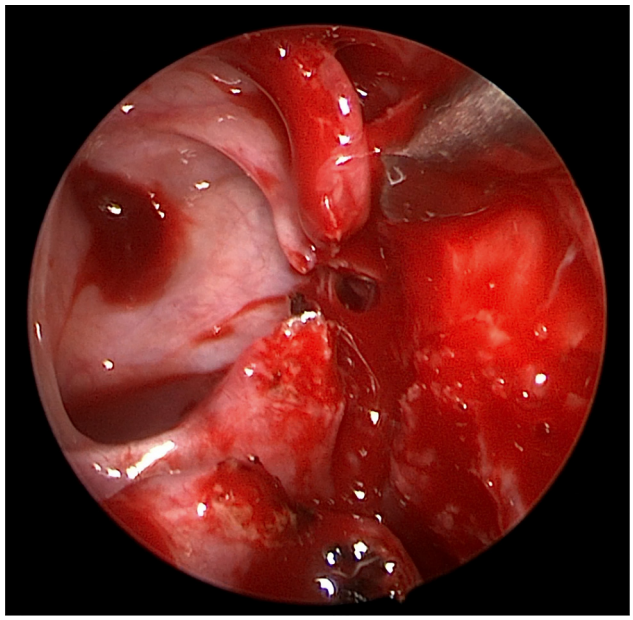

Figure 3 The right olfactory strip is being elevated superiorly with a Cottle elevator to protect it during the sellar dissection. This maneuver also exposes the sphenoid rostrum, which must be drilled down for wide access to the sella.

The dissection begins by infracturing and outfracturing the bilateral inferior turbinates. Following dissection of the maxillary and ethmoid sinuses, we identify the superior turbinate. The inferior third of the superior turbinate is transected, leading to the natural ostium of the sphenoid sinus posteromedially (Figure 1). The ostium is bluntly dilated and opened superiorly, medially, and laterally at first; limited dissection inferior to the natural ostium is performed to prevent inadvertent injury to the posterior septal branch of the sphenopalatine artery in case a nasoseptal flap is needed for skull base reconstruction. A similar dissection may now be performed in the opposite nasal cavity, though we tend to lateralize the middle and superior turbinates instead of resecting them partially.

Traditionally, a nonpneumatized sphenoid (eg, conchal or presellar),[15] which is relatively common in pediatric patients before age 10,[16] was a contraindication to transnasal skull base surgery.[17] However, recent evidence suggests that this is no longer a limiting factor, as the sphenoid sinus can be safely drilled open with powered instrumentation for access to the sella, generally with intraoperative image guidance (Figure 2).[18-20] However, in the face of a nonpneumatized sphenoid, the surgeon must be mindful of the approximate locations of the planum superiorly, the optic canals and carotid arteries laterally, and the sella posteriorly, as these structures are completely encased in bone. The medullary bone filling the sinus tends to also bleed significantly, so a diamond bur is recommended for its hemostatic properties.

Once the bilateral sphenoidotomies have been performed, an anteriorly directed horizontal incision from the right sphenoidotomy can be made with needle tip monopolar electrocautery to approximately the former level of the anterior head of the middle turbinate. This incision is purposely made low in order to avoid the olfactory strip superiorly.[21] The olfactory strip may be elevated superiorly to expose the sphenoid rostrum (Figure 3). A contralateral septal flap can then be elevated along the opposite side of the sphenoid rostrum to connect the cavity to the contralateral sphenoidotomy. At this point, the contralateral olfactory strip may be elevated superiorly as well.

With the posterior septectomy made, attention is then turned to using a high-speed drill to remove the posterior bony septum and the sphenoid rostrum posteroinferiorly to the clivus. Mucosa overlying the sella should be gently removed—beware of aggressive stripping as that may lead

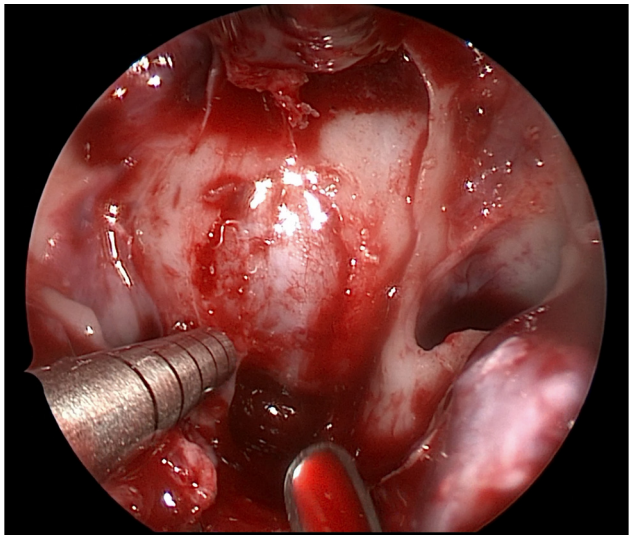

Figure 4 Wide exposure of the sella following bilateral sphenoidotomies and removal of intersinus partitions. Here, part of the sellar face has been removed and the dura is evident. Also note the use of the 2-surgeon, 3-hand approach, with the neurosurgeon dissecting through the right nostril with 2 instruments, and the otolaryngologist providing endoscopic visualization via the left nostril.

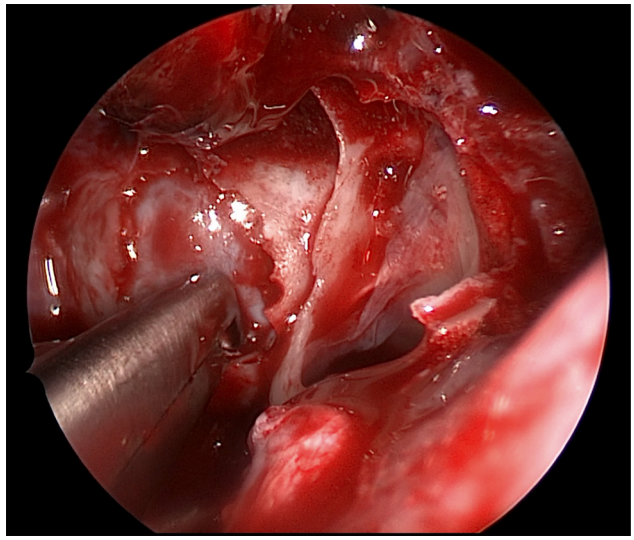

Figure 5 Up and down biting Kerrison rongeuers are used to remove more of the sellar face for wide access.

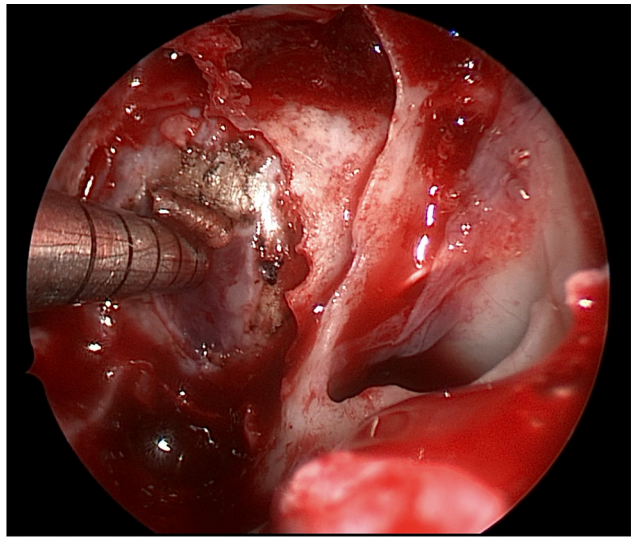

Figure 6 The superiorly-based U-shaped dural incision has been made with a retractable knife, and the suction is seen gently pushing the flap superiorly, exposing the pituitary adenoma posterior to the dura.

to significant bleeding. The planum sphenoidale and intersinus septa should be widely visible. The intersinus septa should each be drilled down carefully flush to the sella, with care not to pass point and violate the dura. The drill is a safer option to take down these septations because they are often attached to one of the carotid arteries, and any torqueing may potentially lead to vascular laceration. As the sphenoid sinus is often incompletely pneumatized in children, some patients will present with the conchal pattern of sphenoid pneumatization. In these cases, extensive, careful drilling is required, with frequent correlation of the depth of dissection with the image guidance probe.

The dura of the sella should be exposed without violating it (Figure 4). Some tumors are extremely expansile and have caused chronic thinning of the sellar bone. In these cases, the bone can be gently fractured using a curette to expose the dura. Systematic removal of the sellar bone can be performed using a combination of Kerrison rongeurs, curetting, and a drill with a diamond burr (Figure 5). A helpful rule is looking for a "meniscus" when the dura is gently palpated—as the dura is pushed away from the overlying sellar bone, the shadow produced under the bone gives the surgeon a clue as to how much more exposure is possible before the cavernous sinus is reached. The dura should be exposed to the limits of the opticocarotid recesses laterally, the clival recess inferiorly, and just inferior to the tuberculum sella superiorly. Prior to entering the dura, careful hemostasis may be performed with topical oxymetazoline and judicious use of suction electrocautery.

Resection

Once the approach to the sella is complete, the neurosurgeon enters the surgical field and the rhinologist repositions opposite the patient to hold the endoscope through the left nares. The dura is cauterized with bipolar electrocautery. There are numerous ways to incise the dura to access the pituitary gland and tumor. We favor a superiorly-based U-shaped incision made with the retractable knife, cutting only through the dura and not into the gland (Figure 6). The flap is then retracted superiorly and a frozen section is sent from the tumor specimen. Using 1- or 2-handed technique, the neurosurgeon removes the tumor and preserves the normal pituitary gland, which is typically displaced by the tumor. The diaphragm sella is the

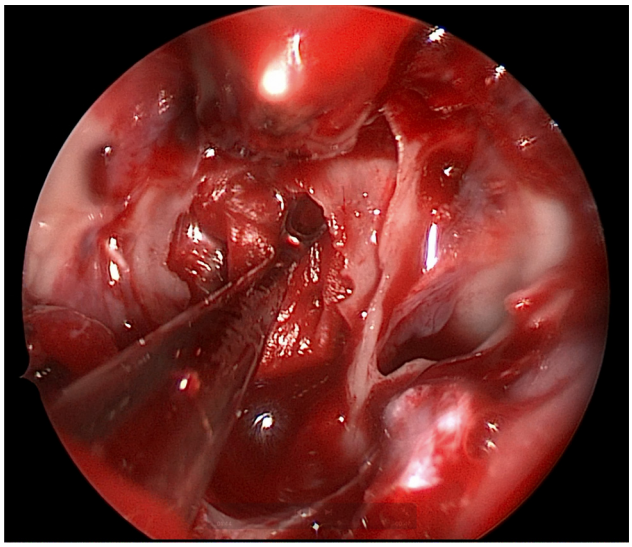

Figure 7 When an intraoperative CSF leak is present, an epidural, intracranial underlay of collagen matrix (Duragen) is tucked under all edges of the sellar face to provide a watertight seal.

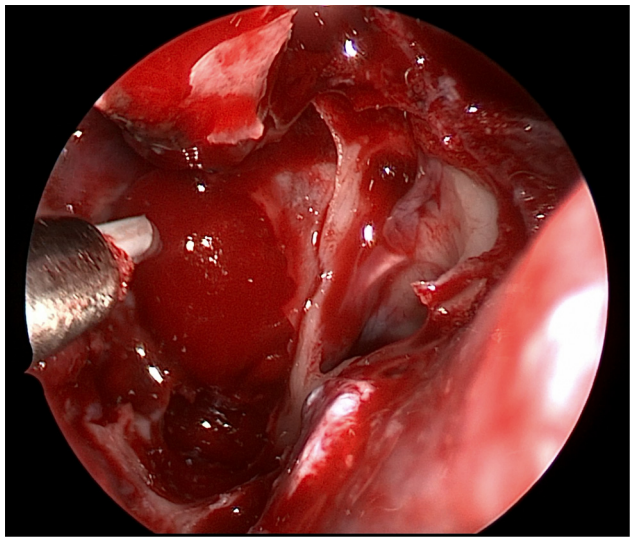

Figure 8 With the underlay in place, a small amount of Fibrin glue is placed over the repair to further reinforce the watertight closure. Following, the nasoseptal flap is placed as an overlay to cover the entire sella.

posterosuperior extent of dissection, and descent of the diaphragma is frequently a sign of adequate tumor resection and decompression. At the same time, it is through removal of tumor off of the diaphragma that intraoperative CSF leaks may occur from microtears. In most cases, the tears are small and the leak is low flow. CSF leaks can be identified by the presence of a small but steady amount of clear fluid dripping from the surgical cavity.

Reconstruction

Following complete tumor resection, the sella is inspected for the presence or absence of an intraoperative CSF leak. Sphenoid sinus mucosa surrounding the surgical cavity where mucosal grafting or flap may drape over should be removed to prevent formation of mucoceles. A potential intracranial, epidural space between the sellar bone and dura is elevated bluntly. The diaphragma is reduced using a sheet of synthetic dural matrix tucked into this epidural space. If no CSF leak is identified, a free mucosal graft may be used to provide coverage of the skull base defect as an overlay. Small (approximately 1 $\times$1 cm) pieces of dry collagen sponge may be placed around the edges of the mucosal graft to anchor it in place, followed by application of microfibrillar collagen into the surgical cavity. A small amount of moist strip gauze is then packed into the sphenoid sinus to provide a stenting effect.

If a CSF leak is found, then reduction of the diaphragma with dural substitute, such as collagen matrix (Duragen), when performed adequately, should demonstrate no further leakage of clear fluid around the edges (Figure 7). A small amount of fibrin glue is then applied over this underlay layer to create a watertight closure along the defect edges (Figure 8). Though there is some evidence that free mucosal graft closure is more than adequate for CSF leak repair, we prefer the use of a vascularized pedicled nasoseptal flap in all cases of intraoperative CSF leak.[22] As mentioned above, details of nasoseptal flap placement and contouring, as well as repair of large skull base defects, will be discussed elsewhere in this text.

Once all reconstruction is completed, a deep extubation is preferred to prevent undesired positive pressure from disrupting the repair. In rare cases, this may produce pneumocephalus. For this reason, temporary placement of nasal trumpets to bypass the surgical site should be considered in case the patient requires bag mask ventilation. The patient is admitted to the neurosurgery intensive care unit for monitoring of central diabetes insipidus, hormonal imbalances, and routine surgical postoperative care, with the endocrinology service to co-follow while the patient is hospitalized.

Postoperative care

Nasal saline sprays may be started as early as 1-2 days postoperatively to help loosen crusts and promote mucociliary clearance. Parents and patient are counseled on maintaining "sinus precautions" to avoid increasing intracranial pressure, including refraining from nose blowing, straining (routine use of stool softeners), leaning forward or lifting heavier than 15 lbs, and open-mouth sneezing. The vast majority of patients are seen in the office at 2 weeks postoperatively. Some patients are able to tolerate removal of nasal dressings and debridement in the clinic, though this is not always the case given patient age and maturity. If the latter is true, then dressings and a single debridement is performed in the operating room under general anesthesia at approximately 2 weeks postprocedure. As most patients do not have preexisting chronic rhinosinusitis, minimal manipulation of the mucosa and premature scar removal are

necessary. The surgical cavity is evaluated at that point to ensure that there is no postoperative CSF leak or potential for mucocele formation. Following this visit, the patient will generally follow up with the neurosurgeon for surveillance over time. In our experience, the incidence of developing clinically significant sinusitis following skull base surgery in this population is very low.

Outcomes

Most reports of surgical outcomes for pediatric pituitary tumors are based on microscopic transsphenoidal approaches to the sella. The first multi-institution large series of endoscopic transsphenoidal transsellar surgery in pediatric patients included 27 patients within a ten-year span, of which 12 patients had pituitary adenomas.[23] In this cohort, all patients had a gross total resection, while no mortalities, neurological complications, late sinonasal sequelae developed, though 1 patients developed a postoperative CSF leak. The same group later published on a comparison of outcomes following either microscopic vs endoscopic approaches to the sella and parasellar region, and found that the endoscopic cohort exhibited significantly lower postoperative pain scores, mean hospital length of stay, and need for blood transfusion, with no differences in surgical complication rates.[24] A systematic review comparing the endoscopic approach to microscopic and/or open transcranial approaches for giant pituitary adenomas found that the endoscopic approach was associated with a higher rate of gross total resection and improved visual outcomes.[25] Finally, in the largest series with literature review to date, Perry et al reported on 39 patients surgically treated at a single institution as well as 1,284 patients across 37 studies.[26] Overall, long-term complications included diabetes insipidus (3%), postoperative CSF leak (4%), permanent visual dysfunction (6%), and hypopituitarism (23%). The long-term cure rate following all treatment modalities was approximately 80%.

As a frontier in skull base surgery, data on craniofacial growth and development following endoscopic skull base surgery is currently scarce. However, in the authors' experience, even the most extensive of intranasal/skull base dissections have had an impact on this domain, with no occurrences of nasal deformities or midface hypoplasia. In addition, though transient radiographic sinusitis is evident during the postoperative period up to approximately 6 months, most cases resolve by 24 months on surveillance imaging.

Conclusions

Endoscopic pituitary surgery in pediatric patients, especially in a multidisciplinary team approach, is safe and effective in resolving symptoms related to tumor compression, achieving a tissue diagnosis, and definitive tumor resection. The main challenges for the rhinologist/skull base surgeon include establishing a wide surgical corridor within the smaller anatomic confines of the pediatric nasal cavity, the need to potentially drill out an incompletely pneumatized sphenoid sinus, and using smaller instrumentation. Close collaboration and constant communication with the pediatric neurosurgery and anesthesia staff is critical for ensuring good outcomes.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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