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Pediatric Intracavernous Sinus Lesions: A Single Institutional Surgical Case Series and Review of the Literature

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BACKGROUND: Pediatric intracavernous sinus tumors are exceedingly rare and thus poorly characterized. Their neurosurgical management is challenging and diagnostic, and management guidelines are limited.

OBJECTIVE: To report our institutional experience with the surgical resection of pediatric intracavernous sinus tumors. We also compare and contrast our results with the 14 cases of pediatric intracavernous sinus lesions in the current literature.

METHODS: A retrospective descriptive analysis of consecutive pediatric patients (ages 0-18 yr) presenting to our institution with a diagnosis of an intracavernous sinus lesion was performed. From January 2012 to January 2017, 5 cases were identified. Eleven patients with secondary invasion of the cavernous sinus (2 meningiomas, 7 pituitary adenomas) or dermoid tumors involving the cavernous sinus (2) were not included in our review.

RESULTS: Surgical resection via a frontotemporal orbitozygomatic approach was performed in all cases by a single senior neurosurgeon (M.L.). There were no perioperative or postoperative complications attributable to the surgery or approach. Four of 5 patients remained neurologically stable throughout the perioperative and postoperative period. The fifth patient had a complete resolution of their cranial neuropathies postoperatively. A pathological diagnosis that guided long-term management was obtained in all cases.

CONCLUSION: Neurosurgical management of pediatric cavernous sinus lesions can be safely performed and critically guide future therapies. Surgeon familiarity with cavernous sinus and skull-base anatomy is critical to the successful management of these patients. The benefits of surgery should be balanced against the potential complications and need for a tissue diagnosis in children. The senior author had a significant experience with cavernous sinus approaches in adults prior to initiating use of the approach in the pediatric population.

KEY WORDS: Pediatric neurosurgery, Pediatric neuro-oncology, Cavernous sinus tumors, Skull-base neurosurgery, Orbitozygomatic approach

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Tumors of the cavernous sinus are rare entities.[1,2] The majority of primary intracavernous lesions occur in adults, and include meningiomas and cranial nerve schwannomas.[1] Tumors originating within the cavernous sinus in pediatric patients are exceedingly rare, with the current literature limited to case reports of hemangiomas, dermoid cysts, lymphomas, teratomas, primitive neuroectodermal tumors, and meningiomas.[3-11] Because of the rarity of these tumors in pediatric patients, a consensus on their diagnosis and management in this setting has not been reached. In our single institutional case series, we report the diagnostic workup, surgical management, and outcomes of 5 pediatric patients with tumors of the cavernous sinus.

ABBREVIATIONS: MRI, magnetic resonance imaging; **FTB,** frontotemporal branch; **ATRT,** atypical teratoid rhabdoid tumor

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METHODS

After obtaining institutional review board approval and patient consent, a retrospective case review of

pediatric patients undergoing surgery from January 2012 to January 2017 at Rady Children's Hospital (San Diego, California) for intracavernous lesions was performed. Patient demographics, surgical details and outcomes, lesion pathologies, and long-term outcomes were recorded. 11 patients with secondary invasion of the cavernous sinus (2 meningiomas, 7 pituitary adenomas) or dermoid tumors involving the cavernous sinus (2) were not included in our review. All procedures were performed following an informed consent process in accordance with institutional protocol. The diagnostic workup, decision for surgery, and surgical approaches used in these cases are detailed in the subsequent section.

Online PubMed and MEDLINE queries were conducted for articles written in the English language published from 1900 to May 2017 using a combination of search terms including "cavernous sinus", "pediatric", "intracavernous", and "cavernous sinus (tumor/mass/lesion)". This search was conducted on May 30, 2017. A manual review of the references from each identified manuscript was performed. Articles were included if they were adequate in reporting of their preoperative, perioperative, and postoperative data, patient characteristics, surgical approach, pathological diagnosis, adjuvant treatment, and overall manuscript quality.

Diagnostic Workup

Diagnostic workup was tailored to the patient's presenting neurological symptoms, and always involved Pediatric Neuro-oncology Tumor Board. Additionally, patient-specific coordination of the neuroradiology, neurosurgery, neuro-oncology, and anesthesiology teams was requisite. A comprehensive neurological exam, with a specific focus on the cranial nerves, was performed in all patients. In patients with neurological signs and symptoms concerning for a cavernous sinus lesion, magnetic resonance imaging (MRI; including thin-sliced T2 and pre- and post-contrast T1-weighted images with axial, coronal, and sagittal views) was then obtained to visualize the three-dimensional relationship of any lesions to surrounding structures. Computed tomography scans were also completed to assess the bony anatomy of the cavernous sinus region. Tumors that were thought to be a secondary extension into the cavernous sinus (such as pituitary adenomas) were not included in this analysis.

Decision for Surgery

Due to the lack of evidence-based management of intracavernous lesions of the pediatric population, the decision to offer surgery was always determined by a multidisciplinary team's assessment of the risks and benefits. Relevant features considered include the acuity and severity of symptoms, radiographic features of malignancy, and radiographic features of growth. The possibility of visual compromise significantly lowered the threshold to pursue surgery. If there was a convincing suspicion that the tumor was a dermoid tumor based on radiographic features, they were observed clinically rather than addressed surgically.

Pediatric Cavernous Sinus Approaches – Pediatric Considerations

Frontotemporal orbitozygomatic approaches were used in all cases. All patients were placed in 3-point pin fixation. Patients are then positioned supine with their head rotated contralateral to the area of pathology. Extension of the head was performed so that the ipsilateral malar eminence was positioned at the apex of the field, to allow gravity to pull the frontal lobe from the anterior fossa and the temporal lobe. A curvilinear incision is made from just inferior to the poster aspect of the zygomatic process, anteriorly above the hairline, to a point between the midline and mid-orbital plane based upon the extent of tumor involvement. The initial incision is made using the scalpel followed by use of the Colorado needle to take the incision down to the pericranium.

The scalp is then freed from the temporalis fascia, and the temporalis fat pad identified. We use the interfascial dissection technique to preserve the frontotemporal branch (FTB) of the facial nerve. We initiate dissection anteriorly at the superior temporal line and take it to the zygomatic root. This allows for the elevation of the deep temporalis fascia and interfascial fat pad for the preservation of the FTB.

A monobloc orbitozygomatic craniotomy is performed in all cases. In brief, a single burr hole is made using a matchstick burr at the pterional keyhole (McCarty burr hole). A cutting burr was then used to create a craniotomy inferiorly towards the temporal bone, then posteriorly towards the parietal bone, then turning back superior and anteriorly towards the midline and ending just lateral to the supraorbital notch at the orbital roof. With an intracanalicular supraorbital nerve, a chisel is used to open the foramen to the orbital ridge allowing for safe inferior displacement of the nerve. With an extracanalicular supraorbital nerve, the nerve is displaced inferiorly.

A Penfield 1 is then used to dissect the periorbital fascia free from the superior and lateral orbital walls extending from the most lateral aspect of the orbital surface of the frontal bone to the orbital surface of the zygomatic bone just inferior to the frontozygomatic suture.

An osteotome is used to gently release the superior orbital wall with the craniotomy, which was carried out laterally to the frontal process of the zygomatic bone. The osteotome is then used to create a chevron cut of the zygoma where the frontal process and the temporal process meet or just above the zygomaticofacial foramen. A wedge-type cut is finally made directed anteriorly, just anterior to the articular tubercle of the zygoma. This disconnects the zygoma from the root and allows for the craniotomy to be removed in 1 piece. Care must be taken not to allow for separation at the zygomaticotemporal suture.

Once intracranial, additional projections of the sphenoid wing were removed using the high-speed burr allowing for exposure of the meningo-orbital band. In children, only minimal drilling to flatten the superior orbital wall is required to expose the subfrontal dura. Mannitol and temporary hyperventilation are used as needed to assist in retraction of the frontal and temporal lobes. The superior orbital fissure and anterior clinoid process are then dissected free. We remove the anterior clinoid extradurally using the matchstick diamond burr with copious, continuous irrigation. We always incorporate removal of the optic strut into the approach. If the anterior clinoid process is pneumatized, liberal waxing of this bony area is performed. The proximal dural ring of the carotid artery is then sharply incised to free up the clinoidal carotid artery and gain wider exposure of the cavernous sinus and increasing mobility of the carotid artery. The dura propria is then freed from the cavernous wall and reflected anteriorly. This tends to be more difficult in children given numerous adhesions and increased vascularity.

If needed, the dura is then opened in a C-shaped fashion exposing the Sylvian fissure. The fissure is then split between the frontal and temporal lobes, and fixed, low-profile retraction is used to maintain this corridor. This maneuver can aid in the exposure with regards to cerebrospinal fluid release and brain relaxation.

The cavernous sinus is usually entered via the "Fukushima Triangle", a superior approach bounded by the third and fourth cranial nerves and the dura between the medial and posterior fossa. Once inside the cavernous sinus, the overall steps for dissection of the tumor depended on the location and consistency of the tumor and relationship to anatomic structures. Fukushima dissectors were used to bluntly inspect the intra-

cavernous component, expressing as much tumor as possible. An ultrasonic aspirator, sharp dissection, and careful bipolar electrocautery were also used as needed to dissect tumor free from surrounding neurovascular structures.

Vigorous cavernous venous bleeding is indicative of a decompressed cavernous sinus, and an intraoperative marker of adequate cavernous sinus decompression. Strict hemostasis was obtained using Surgicel Fibrillar (Ethicon, Johnson & Johnson, New Brunswick, New Jersey) to fill the entry site until reasonable hemostasis was achieved. The craniotomy was replaced, and the wound was closed in the standard fashion.

RESULTS

Patient Demographics and Outcomes

Between the years 2012 and 2017, our institution accumulated a series of 5 pediatric patients with tumors primarily originating within the cavernous sinus. Patient characteristics and outcomes are presented in Table 1.

In this review of our institutional data, only tumors with primary involvement of the cavernous sinus were included. Patient age ranged from 6 to 18 yr. There were 4 females and 1 male. Cranial neuropathies were the most common presenting feature, seen in 3 of 5 cases. Only 1 case presented with visual loss consistent with venous congestion of the ophthalmic vein. A separate case had presenting signs and symptoms of optic nerve compression. All imaging studies documented an intracavernous origin of the tumor, with suggestion of possible extension outwards to either the sella or the superior orbital fissure. All surgeries were performed through a frontotemporal-orbitozygomatic resection as described above. The decision to perform the surgery intradurally or extradurally was made at the discretion of the senior author (M.L.). There were no complications related to the surgical approach. The extent of resection was

TABLE 1. Patient Characteristics and Outcome of our Institutional Series

Case number	Sex	Age	Clinical Presentation	Extent of Tumor	Surgical Approach	Results	Pathology	Adjuvant Treatment	Follow-up and Outcome
1	F	13	Right afferent pupillary defect, left inferior quadrantanopsia	Right cavernous tumor with extension into the superior and inferior orbital fissures	Right OZ, intradural, extradural	NTR	Hemangioma	none	24 mo Stable right anterior pupillary defect. No growth of tumor.
2	F	6	Right proptosis and chronic vision loss	Right cavernous tumor. Similar appearing tumors also seen at the bilateral jugular fossa	Right OZ, intradural, extradural	STR	Atypical meningioma (Ki-67 10%), NF2	Proton beam therapy	24 mo Right III, IV, V, VI palsies.
3	F	14	Right facial pain and numbness	Bulk of the tumor within the right cavernous sinus, some extension into Meckel's cave	1) Right OZ, intradural; 2) Right OZ, intradural	NTR	Hemangio-endothelioma	Proton beam therapy	3 month follow-up: Stable postop numbness of V1-3. Rapid regrowth, re-do surgery at 3 month follow-up. 24 month follow-up: resolution of numbness, increased V2 neuralgic pain. No further recurrence. Pain controlled on carbamazepine
4	F	8	Left-sided complete ophthalmolegia	Bulk of the tumor within the left cavernous sinus with some extension into the left superior orbital fissure	Left OZ, intradural	STR	Chondroma	None	18 mo Doing well with stable CN III, IV, and VI palsies. No growth of tumor.
5	M	18	Right-sided complete ophthalmoplegia, ptosis, binocular diplopia	Bulk of the tumor within the right cavernous sinus, some extension into the sella	Right OZ. intradural, extradural	STR (frozen section results as lymphoma)	B-cell CNS Lymphoma	Chemotherapy	12 mo Cranial nerves intact. No residual tumor.

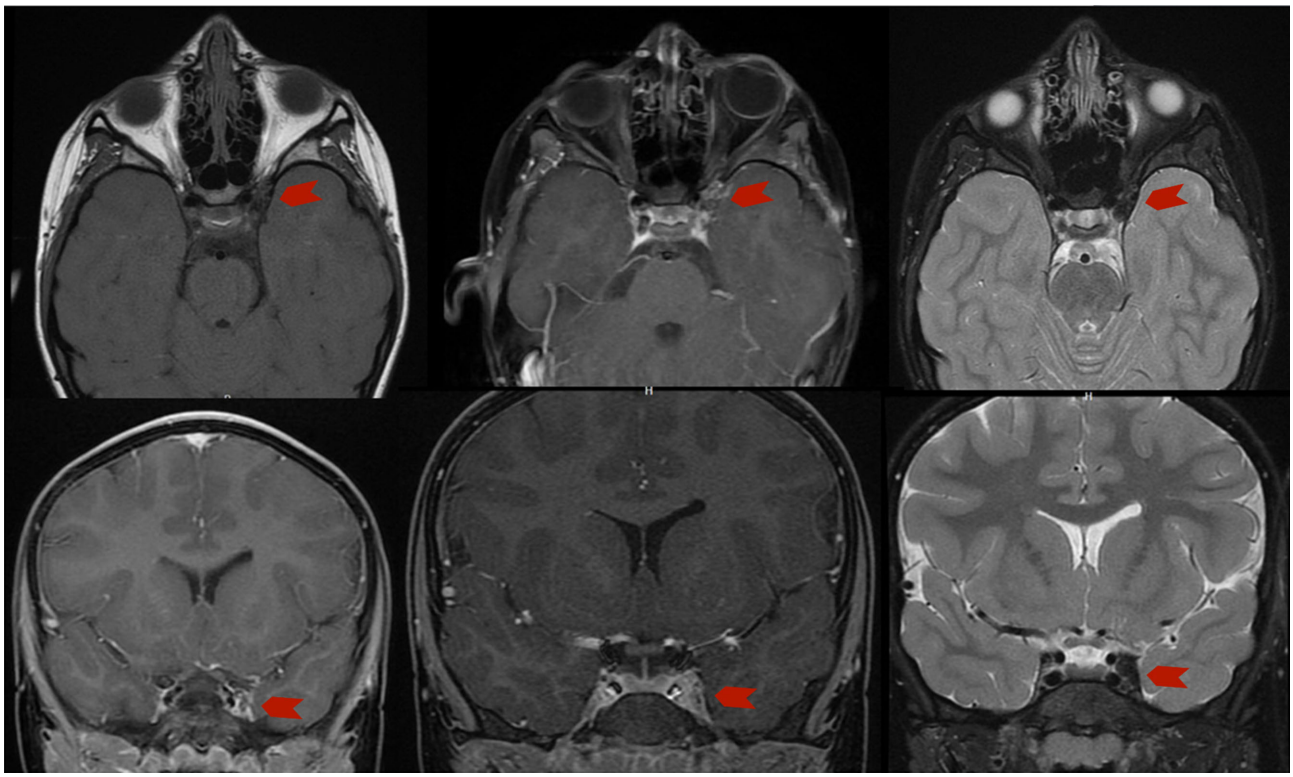

FIGURE 1. *Preoperative MRI showing a left, T1 and T2 hypodense, intracavernous lesion without contrast enhancement, suggestive of a cavernous malformation.*

determined based on intraoperative decision making for patient safety. In cases where the tumor was adherent or inherent to the nerves, it was left alone. (Patient 5's surgery was an intentional subtotal resection after intraoperative frozen section pathology results were revealing for a lymphoma.) No radiographic or clinical evidence of cavernous sinus thrombosis was observed in our patient cohort.

There were no perioperative or postoperative complications in this series. One patient (patient 3) required a second-look operation due to tumor recurrence on follow-up imaging three months after the initial surgery.

There were also no new cranial nerve deficits following surgery, and one patient had complete resolution of their cranial nerve deficits following surgery (patient 5; with the improvement prior to any chemotherapy and directly attributable to the surgical resection). A pathological diagnosis was obtained in all cases, with the decision to include postoperative adjuvant therapy made by oncology. At follow-up, all patients were doing well without any new deficits or complications from the surgeries.

Illustrative Cases

Patient 4

A 7-yr-old girl with 1 yr of decreased left-sided extraocular movement and an MRI demonstrating a possible cavernous malformation in her left cavernous sinus (Figure 1). The patient was initially co-managed conservatively between the neurosurgery and ophthalmology teams, with her strabismus and incomplete ophthalmoplegia stable over 18 mo. Serial MRIs also demonstrated no change in the lesion over this time. However, after 18 mo of observation, the parents noted a further decrease in extraocular movements of the affected eye, and the patient reported decreased visual acuity confirmed by an ophthalmologist. Given the patient's neurological decline an urgent surgery to address the lesion was planned despite stable imaging findings.

A left-sided orbitozygomatic, intradural approach as previously described was performed. Once inside the cavernous sinus, small, firm pieces of tumor were immediately seen, and were expressed in piecemeal fashion using blunt dissection. Ultrasonic aspiration and gentle cautery were used to free the tumor from the surrounding carotid artery and the walls of the cavernous sinus until, brisk, non-pulsatile bleeding was appreciated, which was interpreted as an unobstructed cavernous sinus. Frozen section pathology analysis was consistent with chondroma without any features of malignancy, and the objectives of surgery were deemed accomplished. The patient was neurologically stable postoperatively, and was discharged home on postoperative day 7.

Postoperative MRI imaging demonstrated a near-total resection (Figure 2), which was subsequently stable on serial

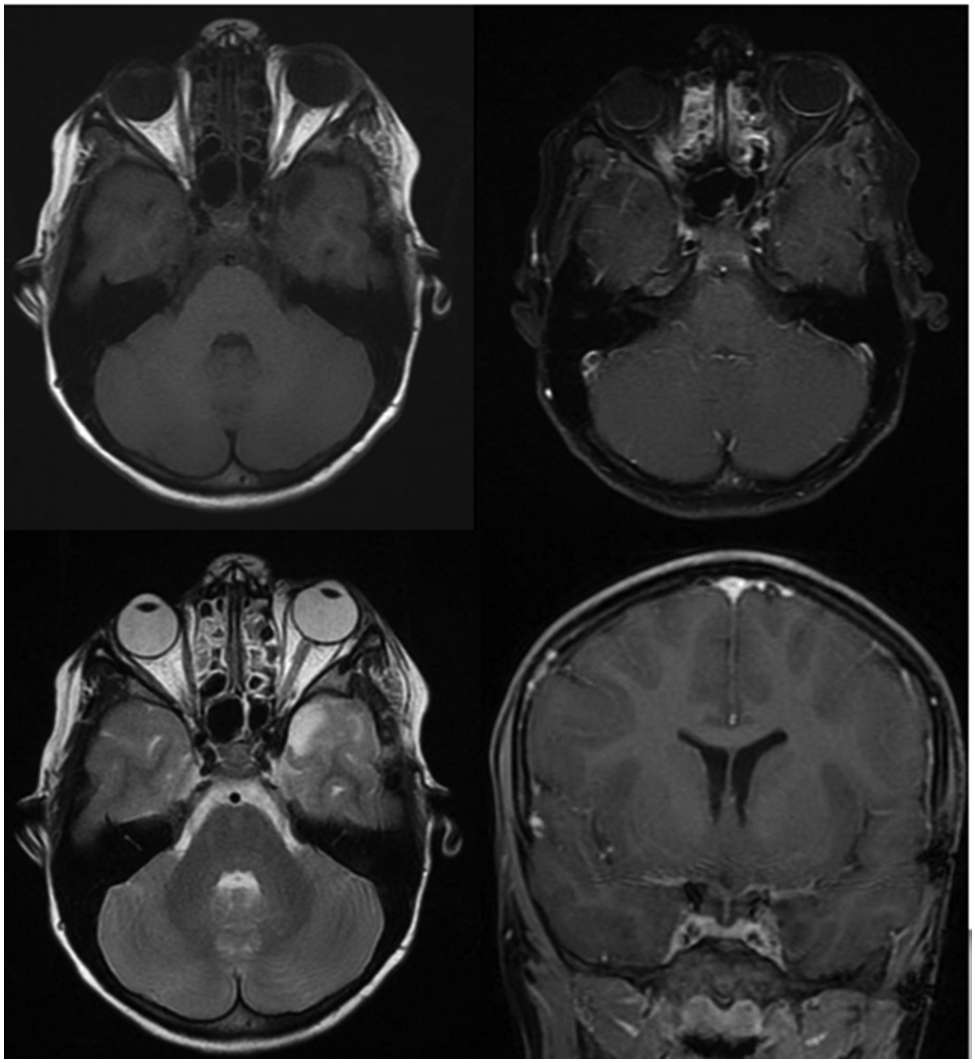

FIGURE 2. *Postoperative MRI, 18 mo after surgery, showing marked reduction of the intracavernous lesion, with pathology results confirmed as benign, ectopic cartilage.*

scans. Close follow-up with ophthalmology, neuro-oncology, and neurosurgery clinics continued for 18 mo, during which she remained neurologically stable with no improvement or worsening of her ophthalmoplegia and strabismus. Because of the lack of malignant histologic features, postoperative chemotherapy or radiation were not offered. The patient has since returned to school.

Patient 5

An 18-yr-old male with no past medical history presented to his pediatrician with new onset right-sided ptosis. He was initially diagnosed with Bell's palsy. The patient's symptoms nonetheless progressed over 1 wk to include right-sided ophthalmoplegia and diplopia. An MRI was obtained, which was concerning for a right-sided intracavernous sinus mass (Figure 3). He was brought to the emergency department (ED) for further workup and management.

Upon presentation to the ED, the patient had a normal neurological exam except complete right-sided ophthalmoplegia, ptosis, and binocular diplopia. His left eye remained intact, and both pupils were equal, round, and reactive to light bilaterally. MRI demonstrated a non-contrast enhancing, T1 and T2 hypointense lesion within the right cavernous sinus.

Given the radiographic uncertainty of this mass, along with the rapid progression of his symptoms, surgery was pursued to obtain a diagnosis and to decompress the cavernous sinus. A right orbitozygomatic craniotomy was used for combined intradural and extradural access to the superior right cavernous sinus.

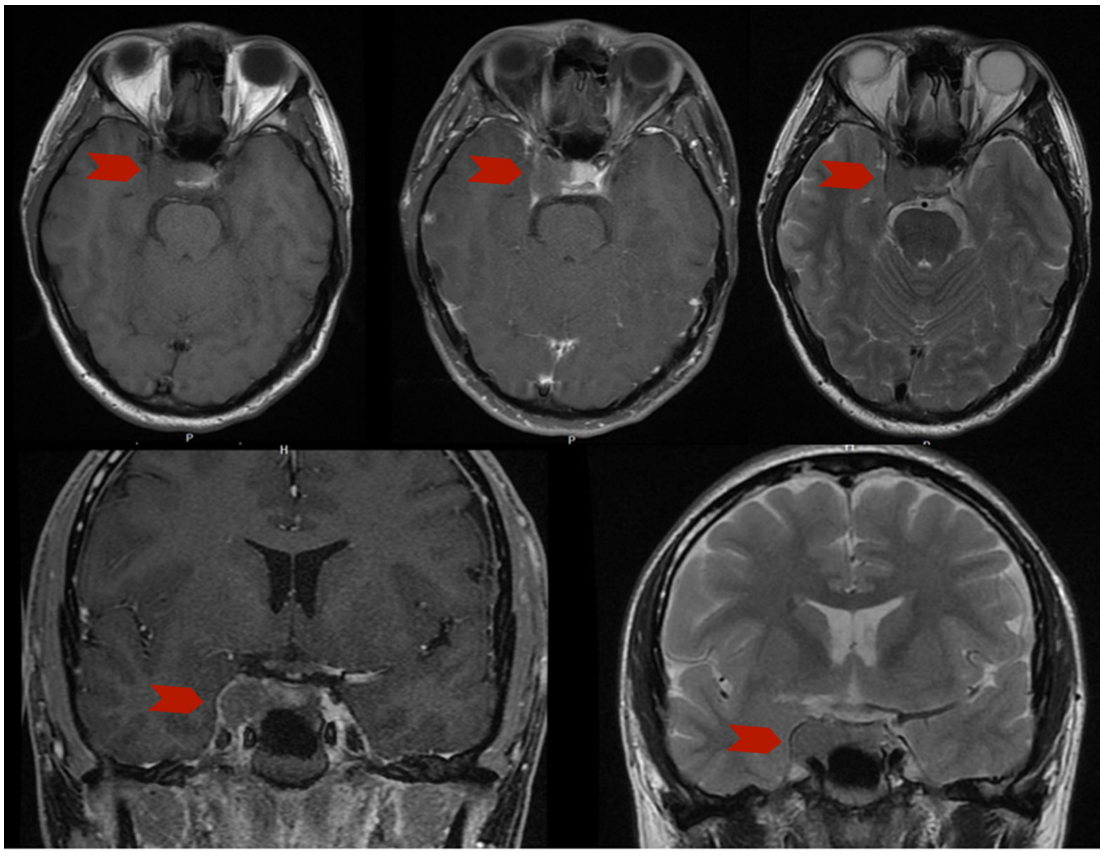

FIGURE 3. *Preoperative MRI showing a right-sided, T1 and T2 isodense, intracavernous lesion without contrast enhancement.*

Once the cavernous sinus was opened, soft, suckable tumor was instantly appreciated. Portions of this tumor were sent immediately for frozen-section pathological analysis. Once the results of the tumor were reported to be lymphoma, no further tumor debulking was performed and the surgery was concluded.

The final pathology was a mature B cell lymphoma, and a further oncologic workup (full body imaging, bone marrow aspiration) was performed by oncology. The patient was discharged from the hospital on post-operative day 4, and had complete resolution of his preoperative symptoms when seen in clinic on post-operative day 10. At his annual follow-up, he had completed his chemotherapeutic course, had no cranial nerve deficits, and his MRI showed complete resolution of the intracavernous lymphoma (Figure 4). His incisions were well healed and he had returned to school with normal neurological function.

Literature Review

Table 2 lists the treatment and outcomes of all cases of pediatric intracavernous sinus lesion identified on literature review. Briefly, in the 3 reported cases of cavernous meningiomas,[9,12,13] 1 patient presenting with strabismus and incomplete oculomotor palsy had no outcome data reported. The remaining 2 patients had injuries of the oculomotor nerve during surgery, with some improvement postoperatively in both, 1 following grafting. Two patients with cavernous sinus hemangiomas and diplopia had improvements in vision following biopsy and Gamma Knife (Elekta AB, Stockholm, Sweden) irradiation in 1 patient, and a pterional approach in the second.[3,5] Outcomes in 3 patients with cavernous sarcomas/lymphomas were variable.[4,7,11] In 3 patients with cavernous sinus teratomas, all had improvement in their presenting oculomotor palsies, while V1, trochlear, and abducens palsies failed to resolve.[8,10,14] The single reported case of a cavernous dermoid tumor had complete resolution of left ptosis and oculomotor palsy following surgery.[6] The case of a cavernous atypical teratoid rhabdoid tumor (ATRT) failed to show any improvement in clinical outcome.[15] One case of a cavernous melanocytoma showed incomplete improvement following subtotal resection and Gamma Knife radiation.[16]

DISCUSSION

Cavernous sinus tumors in pediatric patients are rare, with previous publications on this topic limited to case reports. The above case series is the largest to date, and represents a single

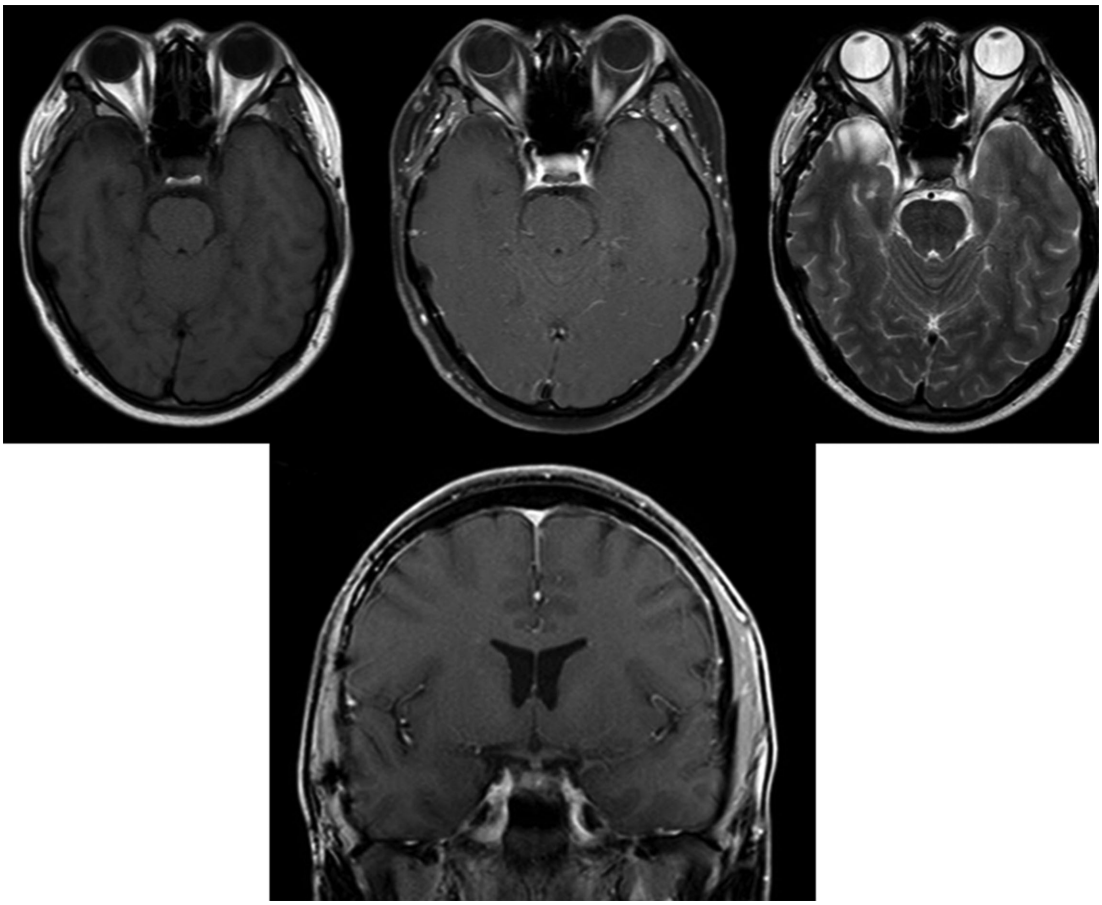

FIGURE 4. *Postoperative MRI, 12 mo following surgery, showing complete resolution of the right-sided intracavernous lesion. Pathology results were confirmed as lymphoma.*

institution's collection of 5 cases of cavernous sinus tumors over the course of 5 yr. Due to the rarity of these tumors, guidelines on their diagnosis and management have not been established.

This case series illustrates the common presentation, workup, and surgical decision tree for pediatric cavernous sinus lesions, as well as the unique operative challenges associated with managing this diverse pathology. As illustrated in case 5, there is often a delay in initial imaging due to a misdiagnosis of cranial neuropathies. Once suspected, an MRI is the preferred imaging modality to identify a cavernous sinus mass lesion, but imaging alone is rarely diagnostic. The decision to operate is thus primarily based upon the patient's neurological status, with expedited intervention warranted in cases of progressive deficits. Fortunately, the pathology in 2 out of the 5 cases in our series was benign, but the radiographic studies and clinical symptoms were inconclusive. In this area of important neurovascular structures, the "watch and wait" strategy may delay diagnosis and worsen morbidity if left untreated and unknown.

Because worsening neurological status is the most common indication for surgery in patients with cavernous sinus lesions, the goal of intervention should be to prevent further neurological decline. In both our series and previous case reports, improvement in neurological symptoms following surgery was variable,[2,5,7-11,15,16] and thus should not be an expectation of intervention.

Given the unique operative challenges associated with cavernous sinus lesions, expert neuropathologic analyses are critical to limit potentially unnecessary intraoperative risk and guide secondary management of such patients. For example, the identification of a chemo-sensitive lesion on frozen pathological analysis early in the surgery (as in patient 5 in this series) argues for a limited resection followed by a likely curative secondary management strategy. Similarly, identifying a tumor as pathologically benign (as in cases 1 and 4 in this series) can help ensure that unneeded, potentially toxic adjuvant oncologic therapies are not pursued.[17–19] Conversely, identification of malignant

TABLE 2. Patient Characteristics and Outcome of Case Reports in the Literature

Reference	Sex	Age	Clinical Presentation	Extent of Tumor	Surgical Approach	Results	Pathology	Adjuvant Treatment	Follow-Up and Outcome
Becherer et al[14]	M	8	Left photophobia, proptosis, oculomotor palsy, decreased visual acuity. Possible trochlear palsy.	Left cavernous sinus	Left frontotemporal orbitozygomatic	STR	Mature teratoma	None	30 mo. Resolution of oculomotor palsy and visual acuity. Continued trochlear palsy.
Kuratsu et al[12]	F	2	Strabismus, incomplete oculomotor palsy	Not listed	pterional approach	STR	Transitional meningioma	Not listed	Not listed
White et al[13]	F	2	Intermittent left exotropia with partial oculmotor palsy	Left cavernous sinus	pterional approach with transection of involved oculomotor nerve	GTR	Psammomatous meningioma	None	30 mo. Required frontalis suspension and strabismus surgery. Improved ptosis and exotropia.
Ceyhan et al[7]	F	4	Bilateral, complete ophthalmoplegia with intact pupillary response	Bilateral cavernous sinus, involvement of the sphenoid sinus and posterior ethmoid sinus	endoscopic endonasal	Biopsy of ethmoid sinus extension	Non-hodgkin's lymphoma	Chemotherapy	Death in 12 d from initiation of chemotherapy from neutropenic sepsis
Ersahin et al[9]	M	6	Left ophthalmoplegia and ptosis	Left cavernous sinus	pterional approach with oculomotor nerve reconstuction with sural nerve graft	GTR	Psammomatous meningioma	None	9 mo. Complete improvement of ptosis, no mention of ophthalmoplegia
Inoue et al[15]	F	1.5	Right ptosis, afferent pupillary defect, exotropia	Right cavernous sinus, extending into the pre-pontine cistern	Right pterional	STR	Atypical teratoid-rhabdoid trumor (ATRT)	Chemotherapy + radiotherapy	29 mo. R oculomotor palsy. Speech delay.
Kalina et al[4]	M	4	Left ptosis, ophthalmoplegia, headaches	Left cavernous sinus, extending to the planum sphenoidale and sphenoid sinus	Needle biopsy of the sphenoid sinus. Technique not listed	Biopsy of the sphenoid sinus extension	Burkitt's Lymphoma	Chemotherapy	Complete resolution

TABLE 2. ***Continued.***

Reference	Sex	Age	Clinical Presentation	Extent of Tumor	Surgical Approach	Results	Pathology	Adjuvant Treatment	Follow-Up and Outcome
Kushen et al[11]	F	13	Right ptosis, ophthalmoplegia, and decline in visual acuity. Headaches	Right cavernous sinus with sphenoid sinus extension. Encasement of the optic nerve and superior orbital fissure. Involvement of the clivus, pituitary fossa, and portions of the left cavernous sinus	Endoscopic endonasal	Biopsy of the sphenoid sinus extension	Ewing's Sarcoma	Conformed radiation, chemotherapy	Progressive, multiple extracranial metastses; Death at 18 months
Lee et al[16]	F	15	Left facial hyperesthesia and paresthesia. Left medial gaze palsy, left ptosis.	Left cavernous sinus lesion with extension into the middle cranial fossa and prepontine cistern	Left subtemporal	STR	Melanocytoma	Gamma Knife	36 mo. Improved diplopia, and left facial hyperesthesia. Stable left ptosis and left facial paresthesia.
Murphy et al[5]	F	15	Left horizontal diplopia, headache	Left cavernous sinus	Left middle fossa, subtemporal	Biopsy of the cavernous sinus lesion	Hemangioma	Gamma Knife	16 mo post-Gamma Knife. Resolution of symptoms
North et al[6]	M	4	Left ptosis and oculomotor palsy. Intact pupillary response	Left cavernous sinus	Not listed	GTR	Dermoid cyst	None	12 mo. Complete resolution
Pikus et al[10]	M	3 mo	Left ptosis and partial oculomotor palsy	Left cavernous sinus	Left pterional	GTR	Mature teratoma	None	12 mo. Resolution of the oculomotor palsy; stable sixth nerve palsy which was stable from postop
Rosenblum et al[3]	F	14	Right eye ptosis and diplopia	Right cavernous sinus	Right pterional	Not listed	Hemangioma	None	18 mo. Complete resolution
Tobias et al[8]	M	14	Right proptosis and visual acuity decline	Right cavernous sinus	Right pterional	GTR	Mature teratoma	None	8 mo. Resolution of the oculomotor palsy. Stable V1 anesthesia, stable abducens paresis (both noted immediately postop)

histologic features (as in cases 2 and 3 in this series) supports a more aggressive resection (when possible), and allows for timely adjuvant therapies.

Considerations in Approaches to the Cavernous Sinus

The original papers by Browder[20] and Parkinson & Ramsay[21] were the first to describe that approaches to the cavernous sinus could be performed safely. Over the following 50 yr, numerous authors have suggested modified approaches based upon the tenet of minimizing brain retraction by maximizing bone removal from the skull base.

Yaşargil[22-24] described transsylvian (pterional) approaches to lesions in the sellar and parasellar regions using frontotemporal or fronto-orbital craniotomy with/without sphenoidal osteotomy.

Hakuba et al[25] described 4 mainly intradural approaches using the lateral wall of Parkinson triangle to address lesions in the cavernous sinus. They utilized frontotemporal or subfrontopterional approaches. They additionally described transpetrosal-subtemporal approaches to the posterior cavernous sinus, which we did not utilize given a lack of pathology in this region in our current series.

Dolenc[26-28] was the first to describe intra- and extradural approaches via a combination of pterional and subtemporal approaches. This approach allowed for entry into the cavernous sinus via the lateral wall of the anteromedial, paramedial, and Parkinson triangles. We utilized numerous components of this approach including extradural removal of the anterior clinoid process. None of our cases required exposure of the intrapetrous carotid and we did not skeletonize the periorbital bone so as to avoid the potential for a postoperative pulsatile exophthalmos.

Hakuba et al[29] in 1989 described the combined orbitozygomatic infratemporal epidural and subdural approach. It was essentially this approach with the subsequent modifications by Pieper and Al-Mefty[30] that we used in our cases. The cavernous lesions can be accessed via the lateral and superior walls in this approach. Anterior transpetrosal osteotomies were not required given an absence of lesions in the posterior fossa. Delashaw et al[31,32] have additionally published modifications of the approach as have Fujitsu and Kuwabara,[33] who proposed removal of the lateral orbital rim and zygomatic arch. We felt that the modifications proposed by Al-Mefty and Anand[34] in which the coronoid process of the mandible is cut were not required in our series.

Additionally, we did not utilize the small pre-auricular subtemporal approaches or larger subtemporal–pre-auricular infratemporal fossa approaches suggested by Perneczky et al,[35] Knosp et al,[36] and Sekhar et al[37] respectively, or the transmaxillary and lateral orbital wall approaches described by Couldwell et al[38,39] that required either enlarging the foramen rotundum or a lateral orbital wall approach.

CONCLUSION

Cavernous sinus lesions in pediatric patients are rare and operatively challenging. Goals of surgery should prevent future neurological decline, and provide a pathological diagnosis to guide secondary therapies. A familiarity with the complex anatomy of this region, and skull-base surgery in general, is critical to the successful operative management of this pathology.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

The authors present a single institution case series of pediatric cavernous sinus lesions managed surgically. This is a very rare problem and there is little information in the literature regarding treatment. A systematic approach, as advocated by the authors allows for the best chance for good outcomes in the this patient population.

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