



Endoscopy

Endonasal microscopic removal of clival chordomas

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Abstract

Introduction: Clival chordomas have traditionally been removed using a variety of anterior and lateral skull base approaches. Herein, we evaluate the outcomes of patients who underwent an extended endonasal transsphenoidal removal of a clival chordoma.

Method: All consecutive patients with a clival chordoma treated using an endonasal microscope approach were identified. In 8 cases, frameless surgical navigation was used, and in 4 cases, endoscopic assistance was used. Patients treated with prior radiotherapy were excluded.

Result: Over 5 years, 18 procedures were performed on 14 patients (7 females; mean age, 47 years). Patients were followed from 3 to 58 months (median, 20 months). Mean tumor diameter was 32 ± 17 mm; 7 (50%) patients had intradural extension. Postoperative MRIs after the initial operation showed gross total, near-total (>90%), and subtotal resection in 43%, 43%, and 14% of patients, respectively. Use of the endoscope was associated with gross total or near-total tumor removal in 4 of 4 cases. Tumor regrowth occurred in 2 (14%) cases 10 and 12 months after the initial surgery and before radiotherapy. Two patients had multiple operations, in one as a planned staged operation, and in the other, 3 additional debulkings were performed despite an initial gross total removal. Nine patients, all with CS invasion, had subsequent stereotactic radiation. Of 10 patients with cranial neuropathy, 80% improved or resolved including 75% and 67% of sixth and fifth CN palsies, respectively. Complications included one each of adrenal insufficiency and chemical meningitis. There were no CSF leaks or new neurological deficits.

Conclusion: In this small series with relatively short follow-up, endonasal microscopic removal of clival chordomas proved safe and effective with gross total or near-total removal in 86% of patients and improvement of cranial neuropathy in 80% of patients. Endoscopy for aiding tumor removal and assessing completeness of resection, as well as surgical navigation, are recommended for all cases.
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Keywords:

Clival chordoma; Endoscopy; Skull base; Stereotactic radiotherapy transsphenoidal surgery

Abbreviations: ACTH, adrenocorticotropic hormone; CN, cranial nerve; CS, cavernous sinus; CSF, cerebrospinal fluid; DFK, Daniel F. Kelly; F/L, follow-up; GH, growth hormone; LINAC, linear accelerator; MRI, magnetic resonance imaging; NP, nasopharynx; OC, occipital condyle; PB, petrous bone; PBR, proton beam radiation; PrpC, prepontine cistern; SpS, sphenoid sinus; SRS, stereotactic radiosurgery; SRT, stereotactic radiotherapy; SS, suprasellar; TSH, thyroid stimulating hormone; UCLA, University of California, Los Angeles.

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1. Introduction

Chordomas are rare, slow-growing, locally destructive but pathologically benign midline tumors that arise from notochord remnants. They represent less than 0.1% of all skull base and fewer than 5% of primary bone tumors [15,38,40]. Approximately 35% occur in the skull base involving the clival and sphenoccipital areas with the remainder in the sacrococcygeal area. Clival chordomas are most common in the third and fourth decades of life and affect

both sexes equally. Although they begin as extradural tumors, they often invade intradurally, especially into the CS as well as into the subarachnoid space with resultant CN dysfunction and in some cases with brainstem compression [26].

Because of their locally invasive nature into the CS, parasellar structures, and intradural extensions, true microscopic total removal of clival chordomas is typically not possible [35]. Total removal rates range from 12% to 75% for traditional skull base approaches and from 33% to 67% for transsphenoidal approaches. However, extent of resection does appear to correlate with subsequent response to proton beam radiotherapy, radiosurgery, or LINAC-based SRT [9,11,30,41–43]. Given that most clival chordomas have an epicenter at or near the midline skull base, the transsphenoidal route often provides the most direct and minimally invasive approach for their removal. Using an extended transsphenoidal approach, one can reach the parasellar area, upper two thirds of the clivus, and access the medial CS [13,18]. Endoscopic visualization further expands the reach of the transsphenoidal approach for clival chordomas [16,25]. Prior surgical series of patients with clival chordomas have reported outcomes using a sublabial transsphenoidal approach [1,13,36,37,45], a sublabial mid-face degloving approach [1], or a purely endoscopic approach [25]. Here, we report our experience with 14 consecutive patients that had chordoma removal via a direct endonasal microscopic approach using surgical navigation in 8 patients and endoscopic assistance in 4.

2. Subjects and methods

2.1. Patient population

All consecutive patients who underwent an extended endonasal removal of a clival chordoma and who had at least a 3 months postoperative follow-up were included. Patients included in this report were operated upon between August 2002 and February 2007. Patients who had prior radiation therapy were excluded. All procedures were performed by the senior author (D.F.K.) at UCLA or Harbor-UCLA Medical Centers. The Institutional Review Board of UCLA approved this retrospective study of the patient data.

2.2. Data collection

Patients' medical records were reviewed, and pre- and postoperative clinical status, imaging, intraoperative events, postoperative complications, and surgical outcomes were collected. Tumors were classified by location as defined by Al-Mefty and Borba [1]: type I, II, or III base on preoperative MRI. Type I tumors are restricted to only one area of the skull base. Type II tumors extend to 2 or more contiguous skull base areas, but tumor removal is achievable by one approach. Type III, with extension of tumor to several contiguous compartments of the skull base, require multiple approaches for tumor removal. Use of follow-up SRT, SRS, or proton beam therapy was also noted.

2.3. Surgical techniques

As previously described, a direct endonasal transsphenoidal approach to the parasellar and clival area with the operating microscope was used in all cases [18,22]. Frameless surgical navigation (BrainLab VectorVision, Westchester, Ill) and endoscopic visualization were used in 8 and 4 cases, respectively, to assist with tumor removal and to assess completeness of resection.

The procedure is performed through a short endonasal speculum, typically 60 or 70 mm in length (Aesculap, Tuttlingen, Germany, or Mizuho-America, Beverly, Mass). Several specific modifications of the standard endonasal approach are used to reach the infrasellar clival region and to maximize tumor exposure. First, the head is positioned in slight flexion relative to the torso to provide better exposure of the infrasellar region and a more comfortable operating posture. Second, the nostril contralateral to the maximal tumor projection is used for the approach because of the accentuated off-midline exposure of the endonasal approach. In 2 cases, because of wide bilateral tumor extension, a binostril approach was used. In 1 case with extensive CS invasion, the middle turbinate was resected to enhance exposure of the ipsilateral CS. Third, given that in most cases the tumor mass is located in the infrasellar clival region, a wide and extensive bony sphenoidotomy is carried to the floor of the SpS, using rongeurs or a high-speed low-profile drill (Micromax; Anspach, Palm Beach Gardens, Fla). Drilling of the clival bone is performed typically with a 3-mm diamond bit burr. Fourth, given that the tendency of clival chordomas to distort the course of the cavernous and petrous carotid arteries and in some cases the basilar artery, the micro-Doppler probe is used to help localize the course of these vessels [19]. In some instances, the petrous and cavernous carotid arteries may be pushed far anteriorly into the SpS or medially toward the midline. Fifth, in cases with intradural tumor extension, the dura is opened more widely to facilitate tumor removal. Sixth, the endoscope with 30° and 45° angled lenses is now used in all cases to facilitate residual tumor identification and maximize tumor removal. Finally, after tumor removal, if a CSF leak and dural defect are present, the repair is tailored to the size and grade of the leak as recently described [23]. For the largest (grade 3) dural defects, a multilayered closure of abdominal fat, collagen sponge, BioGlue sealant, and 48 hours of lumbar CSF diversion is used [23]. Nasal packing is not used.

2.4. Outcome analysis

Tumor characteristics including size, CS invasion, and intradural invasion were noted based on MRI reports. In patients with tumors compressing the pituitary gland, pituitary function was assessed by standard hormonal testing including serum cortisol and ACTH, free thyroxine and TSH levels, GH and insulin-like growth factor-1, free and/or bioavailable testosterone, and urine specific gravity. Clinic notes were reviewed for pre- and postoperative CN status as

Table 1
Signs and symptoms at presentation

N = 14	No. of patients	%
CN palsy	10	71.4
Sixth nerve palsy	8	57.1
Fifth nerve palsy	3	21.3
Second nerve palsy	2	14.2
Fourth nerve palsy	1	7.1
Seventh nerve palsy	1	7.1
Headaches	7	50
Unsteady gait	2	14.2
Spontaneous CSF leak	2	14.2
Meningitis (aseptic)	1	7.1

well as visual status (visual acuity and visual field tests) and the need for new hormonal replacement. Complication rates were determined from operative and postoperative notes. Tumor removal rates were categorized as gross total, if no residual tumor was seen at surgery and on immediate and 3-month postoperative MRI, near total (>90% volume removal) or subtotal (<90% volume removal).

2.5. Statistical analysis

Extent of tumor resection was compared for dichotomous variables (use of the endoscope, presence of CS invasion, etc) with the Fisher exact test. Extent of tumor resection was compared for continuous variables (such as tumor size) using the exact Wilcoxon rank sum test.

3. Results

3.1. Clinical presentation

As shown in Tables 1 and 2, of 14 patients in this series (mean age, 47 ± 15 years; 50% women), clinical presentation

was diplopia from a sixth nerve palsy in 8 (57%), fifth nerve palsy with facial numbness in 3 (21%), headaches in 7 (50%), progressive visual loss in 2 (14%), unsteady gait in 2 (14%), and a spontaneous CSF leak in 2 patients (with meningitis in one). Based on MRI, maximum tumor size was 80 mm with a mean of 32 ± 17 mm. One patient had undergone 2 prior tumor removals through a transsphenoidal midface degloving procedure 13 and 5 months before his endonasal operation. Before his endonasal operation, he had growing residual tumor but had not received radiation treatment.

3.2. Surgical removal rates

In total, 18 endonasal procedures were performed including 2 patients who had multiple operations; 7 (50%) patients had intradural invasion of tumor confirmed at surgery (Table 2). Pathologically, 11 (78%) of 14 tumors were typical, 2 were chondroid-type, and 1 had mixed features [28]. One patient had type I chordoma. Twelve patients had type II chordoma and required a one-stage operation. One patient had type III chordoma with the need for two-staged endonasal operations [1]. Overall gross total removal, near-total removal, and subtotal removal were achieved at the first operation in 6 (43%) patients, 6 (43%) patients, and 2 (14%) patients, respectively. All 8 patients with near-total and subtotal resections had CS invasion ($P = .015$; compared to only 2 of 6 with gross total removal). The rate of gross total or near-total tumor removal in the 4 patients with endoscopic assistance vs the 10 patients without endoscopic assistance was 100% vs 80% ($P = 1.0$). Tumors with subtotal resection tended to be larger on average (mean, 60 ± 28 vs 27 ± 11 mm for gross total and near-total resections), although this was not statistically significant because of the small sample size in the subtotal group ($n = 2$, $P = .088$, exact Wilcoxon rank sum test) (Table 3).

Table 2
Patient demographics, tumor characteristics, and outcomes

No	Age/ sex	Max tumor diameter (mm)	Tumor location	Intradural extension	Degree of tumor removal	Recurrence	Postoperative radiation	F/U (mo)
1	57/F	10	C	+	Total	–	–	13
2	53/F	14	C + SpS	+	Total	–	–	31
3	58/F	15	C + PB + CS	+	Near total	–	SRT	12
4	55/F	17	C + S + CS	–	Total	+ (3)	SRT and SRS	58
5	32/F	25	C + CS	+	Total	–	–	10
6	28/M	30	C + S + SS	+	Near total	+ (1)	SRT	47
7	22/M	30	C + SpS + NP + CS	–	Total	–	–	3
8	47/M	33	C + CS	–	Near total	–	PBR ^a	16
9	18/M	34	C + SpS + S	–	Total	–	–	30
10	51/F	36	C + OC + PB + SpS + NP + CS	–	Near total	–	SRT	29
11	67/M	40	C + PrpC + S + SS + CS	+	Subtotal	–	SRT	13
12	49/M	41	C + PrpC + SpS + S + SS + CS	–	Near total	–	SRT ^a	24
13	57/F	41	C + PrpC + SpS + S + CS	–	Near total	–	SRT	16
14	65/M	80	C + PrpC + PB + OC + SpS + NP + CS	+	Subtotal	–	SRT	50

F indicates female; M, male; C, clivus; S, sella; SS, suprasellar.

Near-total removal indicates >90%; subtotal removal, <90% tumor removal.

^a Radiotherapy at an outside facility.

Table 3
Tumor removal rates based on size, invasiveness, and use of endoscopy

	Gross total (n = 6)	Near total (n = 6)	Subtotal (n = 2)
Mean max tumor diameter (mm)	22 ± 9	33 ± 10	60 ± 28 ^a
CS invasion ^b	2	6	2
Endoscopic assistance	1	3	0

^a $P = .088$, subtotal vs total and near total resection.

^b $P = .015$, cavernous sinus invasion based on subtotal vs total and near total.

3.3. Repeat operations and tumor recurrence

With a median follow-up 20 months (range, 3–58 months), 2 patients underwent multiple operations and 2 have had tumor recurrence. A 65-year-old man had a planned 2-stage subtotal debulking of an 80-mm chordoma with both chondroid and typical features with extensive bilateral CS invasion and brainstem compression. He has a stable and regressing tumor mass 50 months after his 2 surgeries and subsequent SRT.

A 55-year-old woman with a typical 17-mm chordoma in the infrasellar, retrosellar, and CS areas had 3 reoperations for tumor recurrence. Thirteen months after an initial gross total removal, tumor regrowth was noted, and she had repeat debulking with near-total removal followed by SRT. A

second recurrence developed within 9 months of her second operation and again 8 months later. Endonasal tumor debulking was performed after each recurrence, and in each instance, a near-total removal was accomplished and her sixth CN palsy resolved after each debulking. After her fourth debulking, she underwent radiosurgery of the tumor bed. At last follow-up, 22 months after her fourth surgery and radiosurgery, she has remained recurrence-free. Radiation changes in the brainstem were seen on follow-up MRI, but the patient remained asymptomatic and has been weaned off glucocorticoid therapy.

The other patient with tumor recurrence of a chondroid-type tumor is a 28-year-old man who had an initial near-total tumor removal but had evidence of tumor regrowth 10 months after surgery. However, at 37 months after completing SRT, there has been no further tumor growth.

3.4. Postoperative events and complications

An intraoperative CSF leak was seen in 8 (57%) patients including 2 grade 1 leaks and 6 grade 3 leaks, all of which were repaired uneventfully including 6 with transient CSF diversion with a lumbar drain. There were no instances of bacterial meningitis, although 1 patient did develop aseptic (chemical) meningitis that resolved uneventfully.

Regarding cranial neuropathy, overall, 8 (80%) of 10 patients had resolution or improvement: 2 of 2 with

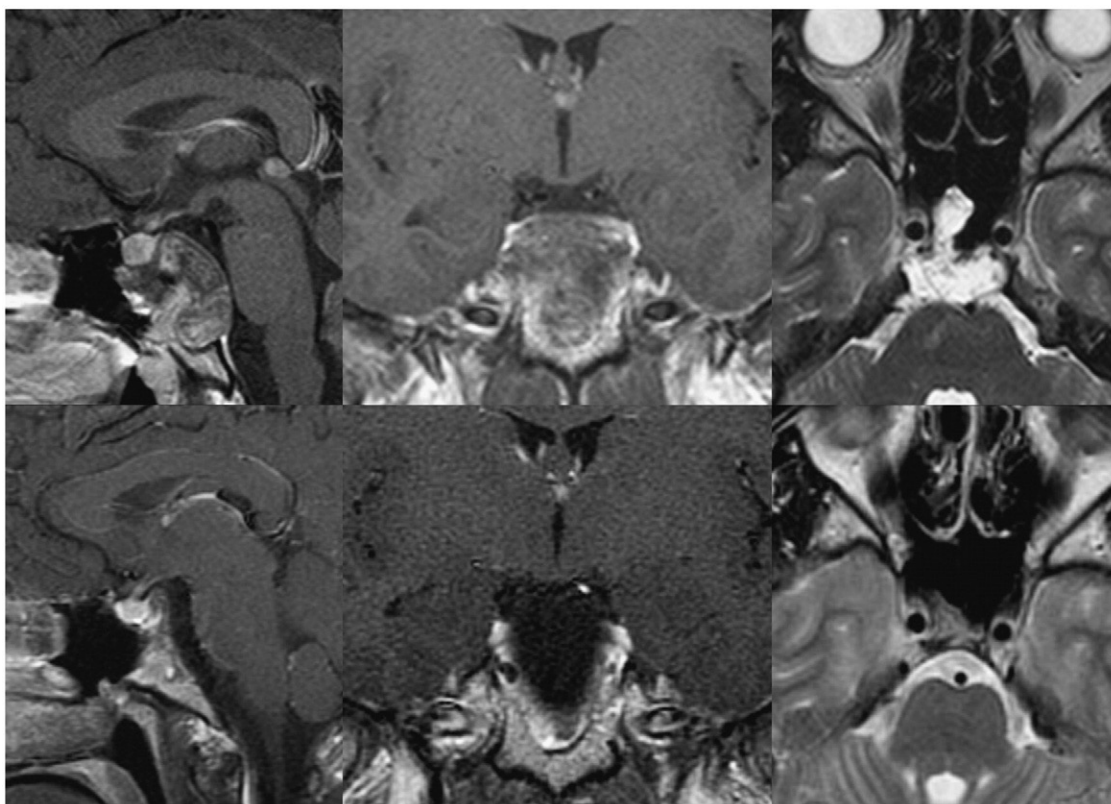


Fig. 1. Upper row: preoperative T1 sagittal, coronal MRI with contrast and T2 axial images. Lower row: same sequences 30 months after surgery. Refer to case history 1.

visual loss improved; 1, fourth CN palsy resolved; 2 (67%) of 3, fifth CN palsies improved; 6 (75%) of 8, sixth CN palsies improved or resolved; and 1, seventh CN palsy persisted. There were no new neurological deficits or vascular injuries.

Regarding pituitary hormonal status, of 4 patients with preexisting deficiency, only 1 developed new cortisol axis loss; he also had transient diabetes insipidus followed by delayed hyponatremia that resolved uneventfully.

3.5. Radiotherapy

In total, 9 patients received stereotactic radiation including 8 of 8 patients with near-total or subtotal tumor resection and 1 patient with an initial gross total resection but with multiple recurrences (as described above). Of 9 patients who received stereotactic radiation therapy, 7 had SRT at UCLA including 1 who had SRT followed by SRS, 1 received SRT at an outside facility, and 1 had proton beam radiotherapy at an outside facility. Of these 9 patients, 8 are recurrence-free or with stable residual at a median follow-up of 20 months. One patient (as described above) with multiple recurrences who received both SRT then SRS has no residual tumor seen at 22 months after SRS.

4. Illustrative cases

4.1. Case 1

An 18-year-old man presented with a 2-month history of progressive headaches and diplopia with partial right CN VI palsy. His MRI showed a $23 \times 34 \times 27$ -mm heterogeneously enhancing clival mass with early brainstem contact (Fig. 1). He underwent a gross total tumor removal through a left endonasal approach with surgical navigation. A grade 1 intraoperative CSF leak was repaired with collagen sponge and BioGlue. His CN VI palsy resolved, and at 30 months postsurgery, he remains recurrence-free and has not received radiotherapy.

4.2. Case 2

A 51-year-old woman developed diplopia and progressive headaches and had a left CN 6 palsy. Her MRI showed a $33 \times 36 \times 25$ -mm heterogeneously enhancing clival mass with extension to the left CS, OC, and PB (Fig. 2). She underwent a near complete tumor removal via a right endonasal approach using surgical navigation; residual tumor was mostly restricted to Meckel cave and the OC area. Pathology confirmed a chondroid chordoma. She received 30 fractions

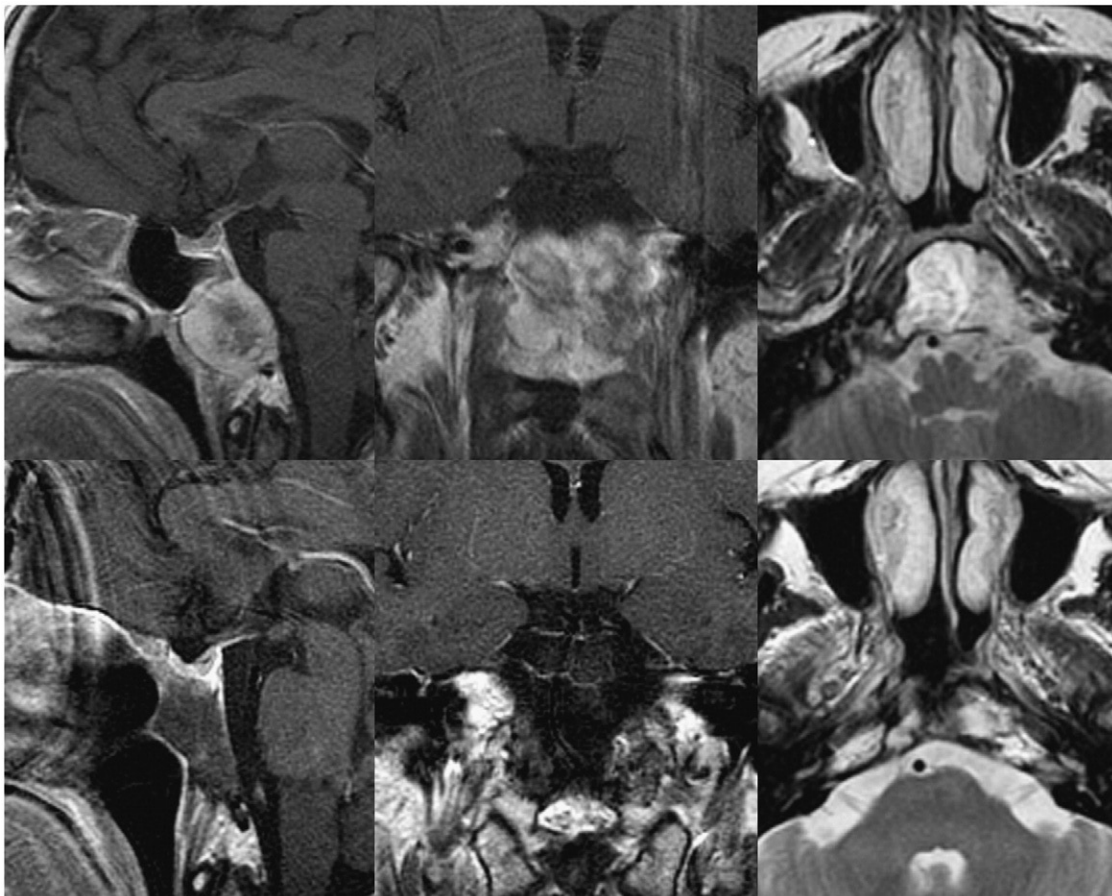


Fig. 2. Upper row: preoperative T1 sagittal, coronal MRI with contrast and T2 axial images. Lower row: same sequences 23 months after surgery. Refer to case history 2.

of SRT and has had no tumor progression with 23 months follow-up. Her diplopia resolved.

5. Discussion

5.1. Summary of findings

Among 14 patients who underwent 18 endonasal transsphenoidal approaches, gross total or near-total removal was achieved in 86% of patients at their initial operation. Surgery improved cranial neuropathy in 80% of patients, and there were no new neurological deficits or postoperative CSF leaks. With a median follow-up of 20 months, 2 instances of tumor regrowth were observed. Of 9 patients with follow-up imaging after radiotherapy, all have either stable residual tumor or no visible tumor at a median follow-up of 20 months.

5.2. Clinical course and outcome

The biological behavior of clival chordomas is difficult to predict. Although they are histologically benign lesions, their invasive growth pattern is often more typical of a malignancy. Several factors including older age, female sex, larger tumor size, prior surgery, and prior radiotherapy have been associated with poor prognosis [5,24,27,43]. In prior studies, headaches and diplopia are the most common presenting symptoms [1,25,26,37,51,52], with sixth and fifth nerve palsies as the most common neurological signs reported [24–26,50]. In a multivariate study [24], diplopia was shown to be associated with longer survival, which may be because such patients present earlier in the natural history of the disease.

In a study of 60 patients, postoperative improvements in fifth and sixth nerve palsies were reported in 23.5% and 51.8% [26]. In our small series, resolution of a sixth nerve palsy occurred in 75% and fifth nerve palsy in 67%. Our findings are similar to that of the study by Frank et al [25], which used a purely endoscope transsphenoidal approach in which sixth nerve palsies improved in 75% of patients. Maira et al [37] also showed a 71% improvement of sixth nerve palsies in 7 patients.

5.3. Role of surgical resection

It has been estimated that patients with a clival chordoma have a 2-year mean survival if left untreated [21,32]. Therefore, radical resection is generally considered the best possible treatment [1,12,24,35,37,47,51–53]. However, given the difficulty of achieving a true gross total tumor removal and the potential high morbidity related to extensive resection and multiple reoperations, aggressive but safe cytoreduction with or without radiation therapy appears to be the best treatment option.

A variety of skull base approaches, including anterior, lateral, and ventral approaches, have been used for removing clival chordomas. In several series published since 1995 in which the transsphenoidal approach was used infrequently or not at all, gross total tumor removal rates have ranged from 7%

to 72% and near-total removal (typically defined as greater than 90% removal) ranged from 20% to 71% [1,12,14,26,46,47,53].

The transsphenoidal route has been used for clival chordomas for over 2 decades [13,36,37,50]. In 1996, Maira et al [37] reported 10 patients with a clival chordoma treated by a sublabial transsphenoidal approach in whom total or near-total removal was achieved in 70% and 20% of cases, respectively. In a series of 105 patients who underwent an extended transsphenoidal approach by Couldwell et al [13], of 18 patients with a clival chordoma, gross total removal was achieved in 67%. Al-Mefty and Borba [1] also used the extended transsphenoidal approach achieving radical removal in 3 (60%) of 5 patients. They also used the transmaxillary midface degloving approach (with or without splitting of the hard and soft palates), particularly for clival chordomas extending toward the craniocervical junction, and reported radical removal in 3 (38%) of 8 patients [1]. More recently, Frank et al [25], over a 6-year period, reported on 11 patients who underwent a purely endonasal endoscopic removal of either a chordoma (n = 9) or chondrosarcoma (n = 2); radical, subtotal (>80%), and partial resection were obtained in 33%, 56%, and 11%, respectively.

5.4. Maximizing tumor removal

These series and our present report indicate that gross total or near-total tumor removal can be accomplished using the transsphenoidal approach in 67% to 89% of patients with a clival chordoma. However, our series (and likely others) clearly has a selection bias in that all the patients except one had their tumor epicenter in the clivus with relatively less tumor extending laterally beyond the cavernous carotid arteries, and without tumor at the craniocervical junction. Such chordomas appear ideally suited for an endonasal approach given that this route provides the most direct anatomical trajectory to the clivus, eliminates the need for an extensive lateral skull base approach, and obviates brain retraction. Provided the nostril of approach is contralateral to the side of greatest tumor extension, a short speculum of 70 mm or less is used, and a wide sphenoidotomy is performed, the direct endonasal route allows excellent access for these tumors, including removal of tumor from the medial CS. Resection of the ipsilateral middle turbinate or a binostril approach will yield additional exposure with a minimal increase in sinonasal complaints [20]. Routine use of the endoscope with 30° and 45° angled lenses for visualizing and accessing tumor beyond the tunnel vision of the operating microscope, particularly in the medial CS and in the inferior aspect of the clivus, is also recommended for all such cases. Several recent anatomical and clinical studies have also shown that the endoscope provides more panoramic and wider visualization into the parasellar region compared with the microscope alone [2,6,8,10,31,33,49]. If these techniques are applied and augmented with surgical navigation, this direct endonasal approach yields tumor removal rates at least equivalent to the more traditional sublabial transsphenoidal approach or the midface degloving transsphenoidal or

transmaxillary approaches and does so with minimal sinonasal morbidity [1,3,13,20,25,36].

5.5. Surgical complications

The most common and serious complications after skull base removal of clival chordomas include CSF leak, meningitis, vascular injury, and new cranial neuropathy [1,12-14,25,26,37,46,47,50,53]. Of the series reporting anterior or lateral skull base approaches for clival chordoma, the rate of CSF leak has ranged from 1% to 30% [1,12,26,46,47,53], and postoperative meningitis has been seen in 2% to 14% of cases [1,12,26,46,47]. New permanent CN deficits have been reported in 4% to 30% [1,12,46,52,53], with new abducens nerve palsy being the most common new neuropathy [26]. Major vascular complications including carotid and basilar artery injuries have ranged from 0% to 12% [1,46,53]. Perioperative surgical-related deaths have been reported in up to 12% of cases [26,46,52,53]. An important point that should be considered is that in almost all these series, patients with prior surgery and/or radiation therapy were included, which likely increases the overall risk of such complications.

In prior transsphenoidal series for clival chordomas, postoperative CSF leaks have been reported in 0% to 10% [13,25,37]. The rate of new cranial neuropathy has been as high as 11% [13,25,37]. Vascular complications were seen in 11% and 16% of 2 series [13,25]. In the present series, no postoperative CSF leaks, new neurological deficit, vascular injuries, or deaths occurred, although 1 patient with prior hypothyroidism developed new adrenal insufficiency.

5.6. Radiation therapy

In the absence of postoperative SRT, the likelihood of chordoma recurrence after gross total resection is relatively high and ranges from 12% to 60% and typically occurs within 3 years of the initial resection [12,48]. Still, routine use of postoperative radiotherapy for clival chordomas remains controversial [12,47]. Proton beam radiation has 5-year survival rates of 54% to 79% [4,7,29,30]. Radiosurgery or SRT has also been used with tumor control rates ranging from 67% to 100% for SRS and from 50% to 82% for SRT [11,17,34,39,41,44]. The initial experience with image-guided hypofractionated radiotherapy remains limited for clival chordomas; however, preliminary experience suggests that this form of radiotherapy can also control tumor growth [11] with a relatively low risk of radiation necrosis. In our small series with a median follow-up of 20 months, of 9 patients with adequate follow-up and who received PBR, SRS, or SRT, or both, only 1 recurrence has occurred. Retreatment in this patient with SRS achieved local tumor control but also was associated with focal radiation necrosis that has now resolved.

6. Conclusions

Given that most clival chordomas are situated with an epicenter medial to the cavernous carotid arteries, a midline

transsphenoidal approach provides the safest and most direct route to their removal and avoids transgressing key neurovascular structures in the lateral CS. The direct endonasal approach performed with a short speculum and the operating microscope yields excellent access to the clivus, medial CS, and intradural space anterior to the brainstem. Endoscopy for wider visualization and frameless surgical navigation for anatomical landmark confirmation likely helps maximize tumor removal. This overall strategy has a low complication rate and a tumor removal rate that is comparable to the purely endoscopic approach and the more invasive sublabial or midface degloving approaches. The role of radiotherapy for clival chordomas remains controversial but appears indicated in most cases when a gross total tumor removal is not possible. Longer follow-up is needed to further assess the efficacy of this more conservative and minimally invasive surgical approach for these skull base tumors that typically defy complete oncological resection.

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