J Neurosurg 109:783–793, 2008

Anterior clivectomy: surgical technique and clinical applications

Clinical article

Ossama Al-Mefty, M.D., Paulo A. S. Kadri, M.D., David M. Hasan, M.D., Gustavo Rassier Isolan, M.D., and Svetlana Pravdenkova, M.D., Ph.D.

Department of Neurosurgery, University of Arkansas for Medical Sciences, Little Rock, Arkansas

Object. Midline clival lesions, whether involving the clivus or simply situated anterior to the brainstem, present a technical challenge for adequate exposure and safe resection. The authors describe, as a minimally invasive technique, an anterior clivectomy performed via an expanded transsphenoidal approach coupled with the use of a neuronavigation on mobile head and endoscopic-assisted technique. Wide and direct exposure, with the ability to resect extra- and intradural tumors, was achieved without mortality and with a low rate of complications.

Methods. Cadaveric dissections were performed to outline the landmarks and measure the window that is created by resecting the clivus anteriorly. The technique was used in 43 patients to resect tumors located at or invading the clivus. The initial exposure of the clivus was obtained via the sublabial transsphenoidal approach. The wall of the anterior maxilla, often on 1 side, was removed to allow a wide side-to-side opening of the nasal speculum. Using neuronavigation, the authors made clivectomy windows by drilling the clivus between anatomical landmarks. Bilateral intraoperative neurophysiological monitoring was used (somatosensory evoked potentials, brainstem auditory evoked responses, and cranial nerves VI–XII).

Results. Of the 43 patients, 26 were female and 17 were male, and they ranged in age from 3.5 to 76 years (mean 41.5 years). Thirty-eight patients harbored a chordoma and 5 a giant invasive pituitary adenoma.

Gross-total resection of the tumor was achieved in 34 cases (79%). Nine patients (21%) had residual tumor unreachable through the anterior clivectomy, and this required a second-stage resection. Four patients developed new transient extraocular movement deficits. One patient developed a permanent cranial nerve VI palsy. Twenty-seven patients with chordoma underwent postoperative proton-beam radiotherapy. Tumor recurred in 19% of these cases. In 3 patients a cerebrospinal fluid leak developed during hospitalization and was treated successfully. Two other patients presented with a delayed cerebrospinal fluid leak after radiotherapy. Only 1 patient, who had previously undergone Gamma Knife surgery, experienced postoperative hemiparesis.

Conclusions. A complete anterior clivectomy via a simple extension of the transsphenoidal approach allows the surgeon access to different lesions involving the clivus or situated anterior to the brainstem. The exposure is similar to that provided by more extensive transfacial approaches. Instrument manipulation is easy. Neuronavigation, endoscopy, and intraoperative monitoring are easily incorporated and enhance the capability and safety of this approach.
(DOI: 10.3171/JNS/2008/109/11/0783)

Key Words • **chordoma** • **clivus** • **maxillotomy** • **neuroendoscopy** • **neuronavigation** • **pituitary tumor** • **transsphenoidal approach**

The merit of the anterior approach to the clivus has been convincingly stated by Laws et al.: "The concept of extended transsphenoidal–skull base approach for a variety of midline lesions is sound…The trajectory afforded by this approach allows the surgeon to work along the axis of the tumor and permits removal of tumors with minimal displacement or distortion of surrounding structures."[43] An anterior approach to the clivus for resection of lesions involving it or using it as a window to access intradural pathological entities has been described and utilized by pioneers and contemporary authors.[14,19,20,22,26–28,48,53,61–63] Widening the exposure by including the maxillary antrum was reported as early as 1917 by Beck[48] and has been well presented and studied by several authors.[6,11,23,58,71]

Today an extensive menu of anterior approaches is available for exposure of clival lesions: transoral, transsphenoidal, transmaxillary, transfacial, transbasal, and infratemporal.[1–3,5,6,9–12,15–17,21,24,27,29,30,32–34,40–48,50–52,54–56,58–61,64,66,67,69,70] Some of the approaches involve extensive dissection of facial, cranial, oral, and nasal structures. Couldwell et al.,[11] in a scholarly work, have demonstrated and estab-

Abbreviations used in this paper: CN = cranial nerve; CSF = cerebrospinal fluid.

lished the advantage and the limitation of each approach. For lesions located on the clivus in the midline and above the hard palate (extra- and/or intradural), we describe a minimally invasive anterior clivectomy that has been used in 43 patients. The anterior clivectomy is performed via a sublabial transsphenoidal approach, and the anterior wall of the maxilla usually on 1 side is removed. We use a neuronavigation system that is applied to a mobile head and an endoscope to achieve maximal exposure, visualization, and resection of the clival lesions. Because the incision is sublabial and the nasal septum is preserved, there have been no visible cosmetic defects or scars.

Methods

The clinical, radiological, and outcome data of 43 patients were retrospectively reviewed. The patients harbored tumors involving the clivus and underwent anterior clivectomy via an expanded transsphenoidal approach. Surgery was performed at the University of Arkansas for Medical Sciences by the senior author (O.A.) between April 1997 and January 2006. Floating-head stereotactic navigation was used for intraoperative localization and to assess the extent of resection. An endoscope was used routinely to assist in visualizing the area behind the clivectomy edges. We included only cases in which wide resection of the clivus was required. Because of their large, lateral extension or because they involved the condyle and created craniovertebral junction instability, several tumors required additional approaches to allow complete resection or stabilization. In these cases the procedures were staged. The anterior approach was used first.

Perioperative Management

Patients underwent a comprehensive clinical, ophthalmological, and endocrinological evaluation. Preoperatively we obtained high-resolution axial CT scans, with coronal and sagittal reconstructions and bone algorithm of the head. Multiplanar MR imaging with and without contrast administration, MR angiography, and MR venography were also conducted.

Neuronavigation was used in all cases. Intraoperative neurophysiological monitoring was undertaken in all patients and included somatosensory evoked potentials, brainstem auditory evoked responses, and electromyography of CNs VI, VII, X, XI, and XII as required by the tumor extension. If manipulation of the sellar contents was anticipated, 100 mg of hydrocortisone was administered at the beginning of the surgery, and the patient was started on a course of steroids, which were tapered during the postoperative period.

Follow-up CT and MR images were obtained during the first postoperative days.

Neuronavigation on Floating Head

After the induction of general anesthesia, the face and the nasal and oral cavities are prepared with povidone–iodine. The patient's head is kept mobile on a foam headrest. We then use a facemask tracer for registration and navigation. In the past we applied the Mayfield 3-pin head tongs to the patient's head to hold the tracer. The Mayfield frame, however, is not secured to the operative table. Instead the patient's head rests on a C-shaped, foam headrest. Early in the series we fixed a post to the skull by screws via a small precoronal incision. The fiducial points are registered and the surgical planning ensues. This allows the patient's head to be "floated," and it is therefore easy to maneuver in the sagittal and lateral planes to achieve maximum exposure of the entire clivus; at the same time one can still use accurate neuronavigation for localization and verification of structures.

Surgical Technique

The patient is placed supine and the head is kept mobile. Neuronavigation registration is obtained. We use C-arm fluoroscopy if needed to confirm accurate localization intraoperatively. A sublabial incision is made for the transsphenoidal approach and extended further laterally on the side of the intended maxillotomy, which is the contralateral side if the tumor extends laterally in 1 direction to allow better exposure of the tumor's lateral extension. Subperiosteal dissection is carried out to expose the nasal mucosa adjoining the pyriformis recess. The dissection continues up the frontal process of the maxilla just below the inferior aspect of the orbit. The most superior aspect of the exposure is the infraorbital foramen containing the infraorbital nerve, which is spared to avoid a postoperative paraesthesia of the cheek. A B-5 bit of the Midas Rex drill is used to create a rectangular opening of the anterior maxillary wall (Fig. 1). Alternatively, an oscillating/reciprocating saw can be used. The osseous gap created by the drilling is minimized. The height of the osteotomy of the anterior wall of the maxilla must be large enough to accommodate the blades of the transsphenoidal retractor so that they can extend into the maxillary cavity as the retractor blades are spread. The maxillotomy incorporates the medial and anterior walls of the maxilla. Any bone left at the medial wall of the maxilla and the lateral aspect of the pyriformis opening is removed using a bone rongeur. The cartilaginous nasal septum is disarticulated from the hard palate and the vomer, and it is then swung contralateral to the side of the maxillotomy. The self-retaining retractor blades are opened maximally to push the nasal mucosa laterally, thereby widening the exposure (Fig. 2). The sphenoid sinus is opened widely. The mucosa along the anterior aspect of the clivus is dissected inferiorly to gain maximal caudal exposure. If needed, part of the superior aspect of the hard palate can be removed using a high-speed drill to gain visibility of the caudal clivus. In this fashion, the entire length of the clivus is exposed from the dorsum sellae to the foramen magnum. Occasionally, the pituitary fossa floor is cut using a rongeur, and the sella dura and the gland are pushed upward to facilitate removal of the dorsum sella. If a clival chordoma is suspected, maneuvers are used to avoid surgical seeding—the walls of the operative bed are coated with fibrin glue and large cotton patties before removing the tumor. After the tumor is completely excised, the cotton patties along with the fibrin glue are carefully removed and all contaminated drapes, towels, gloves, and instruments are replaced.

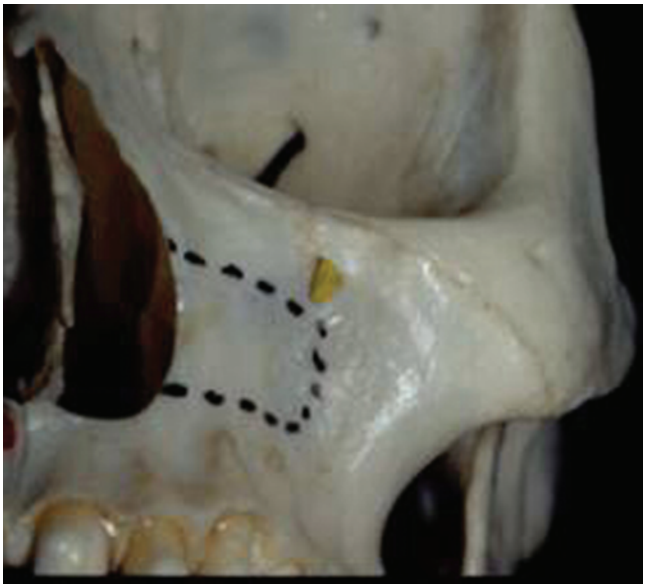

FIG. 1. Photograph of an anatomical model delineating the osteotomy of the anterior wall of the maxilla.

Clivectomy

A clival window between the anatomical landmarks can be drilled with ease, exposing the tumor (Fig. 3). The clivus is then drilled using the diamond bit by angulated high-speed drill from the floor of the sphenoid sinus downward. Care is taken with the lateral borders as they are limited between the optic canals, the petrous and the cavernous segments of the internal carotid artery, and the abducent nerve, limiting the opening of the upper clivus to 16 mm. This widens as one moves caudally on the clivus with the distance between the 2 hypoglossal canals at 34 mm and between the abducent nerves at 20 mm. The vertical distance between the floor of the sella and the inferior margin of the clivus is 30 mm, and the thickest part of the clival bone is 18 mm rostrally and 8 mm inferiorly (Fig. 4). Table 1 details the distance measurements that we obtained in 4 dry skulls and 6 cadavers. Once that window is created, access to the planum sphenoidale, tuberculum sella, sella turcica, the posterior clinoid, the interpeduncular cistern, and the entire clivus down to the anterior lip of the foramen magnum is attainable and safe.

Even reaching laterally to the apex of the petrous bone can be accomplished with the assistance of the neuronavigation system. Extradural and intradural tumor resection is performed and carried out with suction, curette, and rongeur. Bleeding from the cavernous sinus or the basilar venous plexuses, even though it is bothersome, is easily controlled using gel foam and fibrin glue. If the tumor extends intradurally, it is followed through its dural penetration. The dural opening can be extended, as needed, in different directions (Fig. 5). The 30° and/or 70° endoscope is used to assist in the visualization and removal of the tumor that lies behind the dural opening and is not visible under the microscope (Fig. 6). The complementary endoscopic technique had added value to the resection in 18 patients (42%). If intradural dissection is performed, a fascia lata graft is applied intradurally, wider than the defect, and secured to the dural edges with small staples. The fascia graft is reinforced on the outside by fat and sealed with fibrin glue. Fat pieces harvested from the abdominal wall are used to fill the bone defect. The maxillotomy bone is placed with the aid of low-profile microplating.

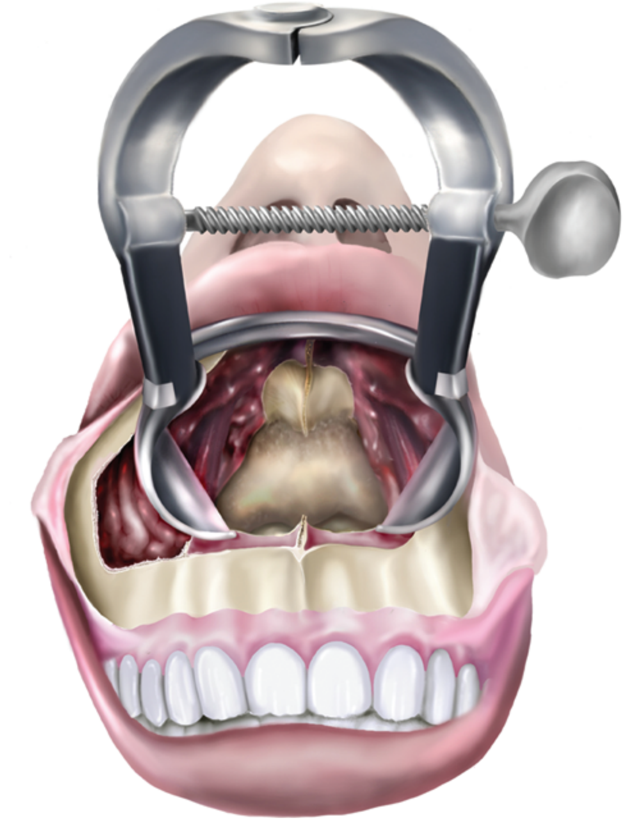

FIG. 2. Artist's illustration of the clival exposure obtained after opening the retractor widely and displacing the nasal mucosa and the septum into the maxilla

Results

Between April 1997 and January 2006, 43 patients (26 females and 17 males) underwent the aforementioned expanded transsphenoidal procedure. The patients ranged in age from 3.5 to 76 years (mean 41.5 years). Thirty-eight patients harbored a chordoma and 5 an invasive pituitary adenoma. Ten patients with chordomas had previously undergone resection at other institutes; in 6 of these 10 an endoscopic approach had been used. The upper clivus was affected in 37 (86%) of the 43 cases; the middle clivus in 40 (93%); and the lower clivus in 19 (44%). In 19 patients (44%) the mass involved 1 cavernous sinus and in 7 patients (16%), the cavernous sinus was involved bilaterally. In 22 patients (51%) the pons was displaced posteriorly due to mass effect (Fig. 7). In 13 patients (30%) the tumor exhibited suprasellar extension (Fig. 8). Twenty-three patients (53%) had intradural extension confirmed during surgery (Fig. 9). Table 2 provides a summary of the area of involvement, tumor extension, clinical presentation, and surgical outcome.

Gross-total resection of the tumor was achieved in 34

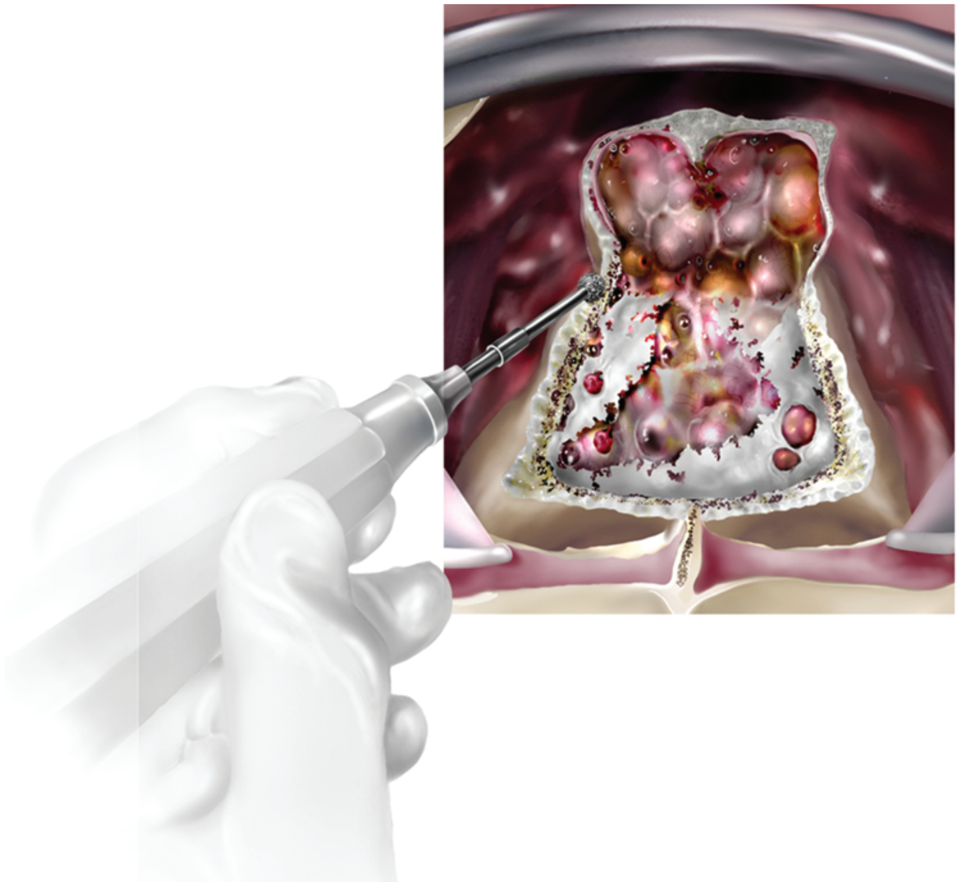

FIG. 3. Artist's illustration demonstrating chordoma exposure after the clivectomy. The wide opening allows ease of instrument introduction and good mobilization.

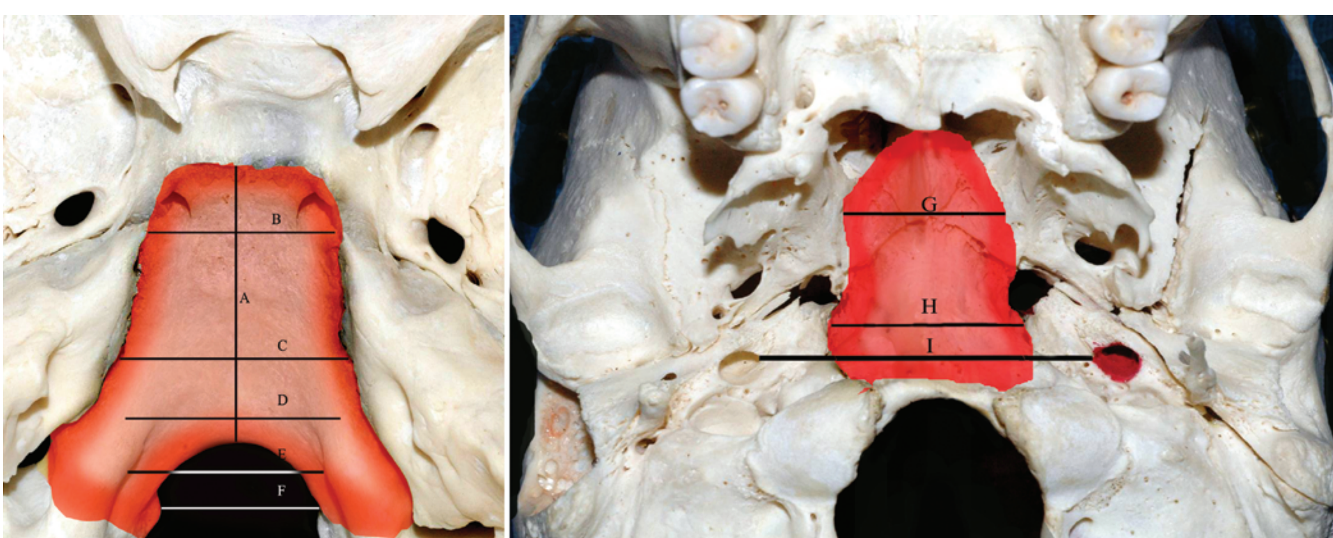

FIG. 4. Photographs of an anatomical model. *Left:* Outline of the maximal border of the clivectomy from its inner aspect: the vertical distance from the base of the posterior clinoid to the anterior surface of the foramen magnum (A); horizontal distance from both petrous apexes (B); horizontal distance from both petroclival sutures at the level of the internal acoustic meatus (C); horizontal distance from both jugular tubercles (D); horizontal distance from both hypoglossal canals (E); and horizontal distance from both anterior portions of the occipital condyle (F). *Right:* Outline of the maximal border of the clivectomy from its outer aspect: the lateral limit of the upper clivus (G); lateral limit of the lower clivus (H); and distance between carotid canals (I).

TABLE 1
*Summary of clival measurements**

Distance	Measurement in mm (range)	Distance	Measurement in mm (range)
A	34 (30–37)	H	22.75 (19–28)
B	21.5 (19–25)	I	51.75 (46–57)
C	32 (30–25)	J	26.5 (22–30)
D	27.3 (26–29)	K	24.5 (22–30)
E	28 (26–31)	L	25.25 (24–27)
F	17.5 (15–21)	M	24.5 (21–23)
G	17.75 (15–22)		

* A = vertical distance from base of posterior clinoid and anterior rim of foramen magnum; B = horizontal distances between both petrous apexes; C = horizontal distance between both petroclival sutures at level of the internal acoustic meatus; D = horizontal distance between both jugular tubercles; E = horizontal distance between both hypoglossal canals; F = horizontal distance between the two most anterior parts of the occipital condyle; G = horizontal distance between the lateral limits of upper clivus; H = horizontal distance between lateral limits of lower clivus; I = horizontal distance between both carotid canals; J = vertical distance in the midline between the floor of the sella and inferior margin of the clivus; K = horizontal distance between both intracavernous portions of the ICA; L = maximal horizontal distance reached at the middle clivus; M = maximal horizontal distance at the lower clivus.

cases (79%), and residual tumors were present in 9 (21%). In 4 patients with residual chordoma a cranioorbitozygomatic approach was used, in 3 a transcondylar approach was used with 2 having occipitocervical fusion, and in 2 a transoral approach was used.

Nine of these patients underwent a second-stage procedure. In 4 patients with residual chordoma a cranioorbitozygomatic approach was used, in 3 a transcondylar approach was used with 2 having occipitocervical fusion, and in 2 a transoral approach was used.

In 4 of the 26 patients with CN VI deficits, function improved after surgery, regaining full ocular mobility. Improvement was documented in 2 of the 4 patients with visual field deficits secondary to chiasmal compression. Four patients developed new transient CN VI nerve deficits. One patient developed a permanent CN VI palsy, which required corrective surgery. One patient had transient diabetes insipidus. Three patients had CSF leakage in the immediate postoperative course; 2 underwent lumbar drainage and in 1 repacking was required. In 2 patients, delayed CSF leakage occurred months after surgery and following high-dose radiotherapy. One patient developed right hemiparesis after suffering a stroke; this patient had previously undergone radiosurgery.

Because of the sublabial incision and the preservation of the nasal septum, there has been no visible cosmetic defect or scar.

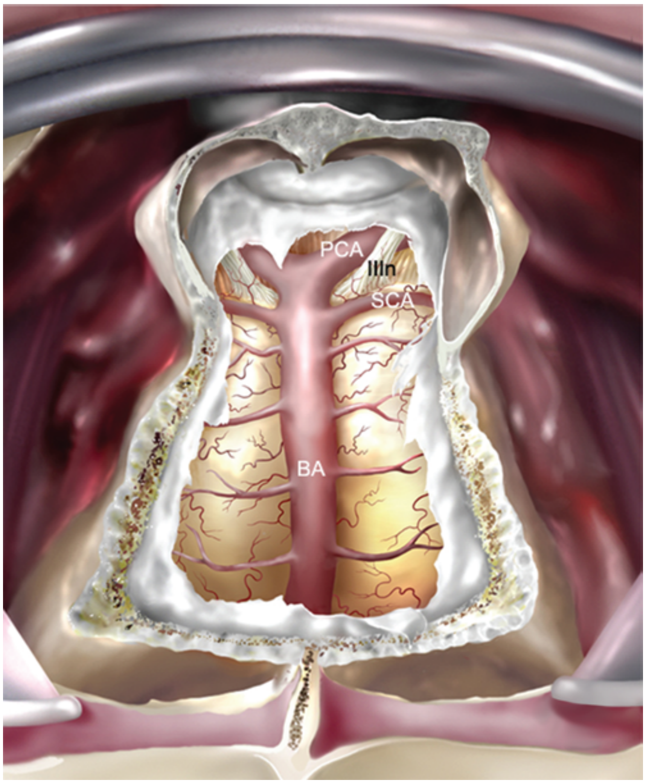

FIG. 5. Artist's illustration of a wide dural opening showing the exposed neurovascular structures through the clivectomy. BA = basilar artery; PCA = posterior cerebral artery; SCA = superior cerebellar artery; IIIn = oculomotor nerve.

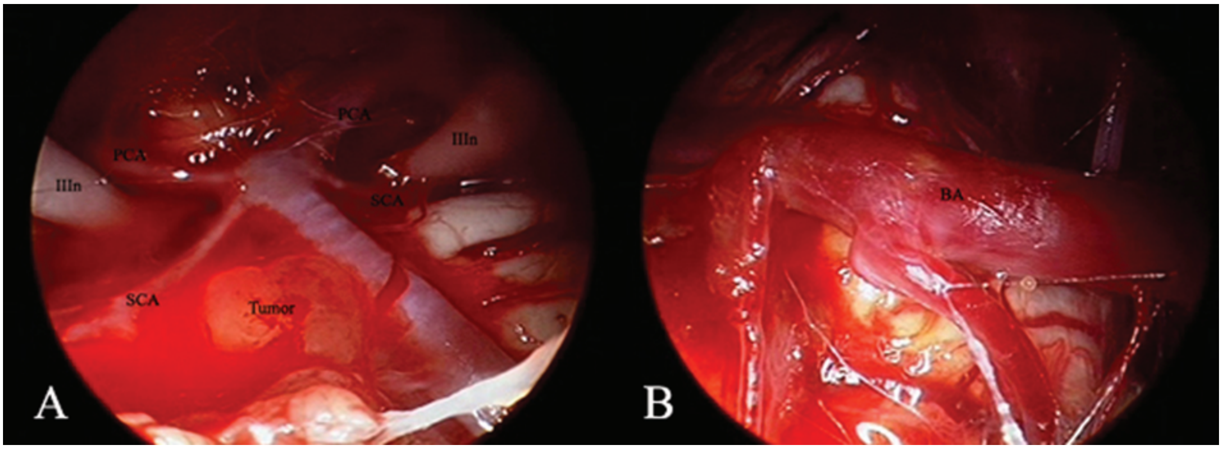

FIG. 6. Intraoperative endoscopic images. A: A small residual intradural tumor is visible using a 30° angled endoscope. B: The tumor is removed from the cerebellopontine angle.

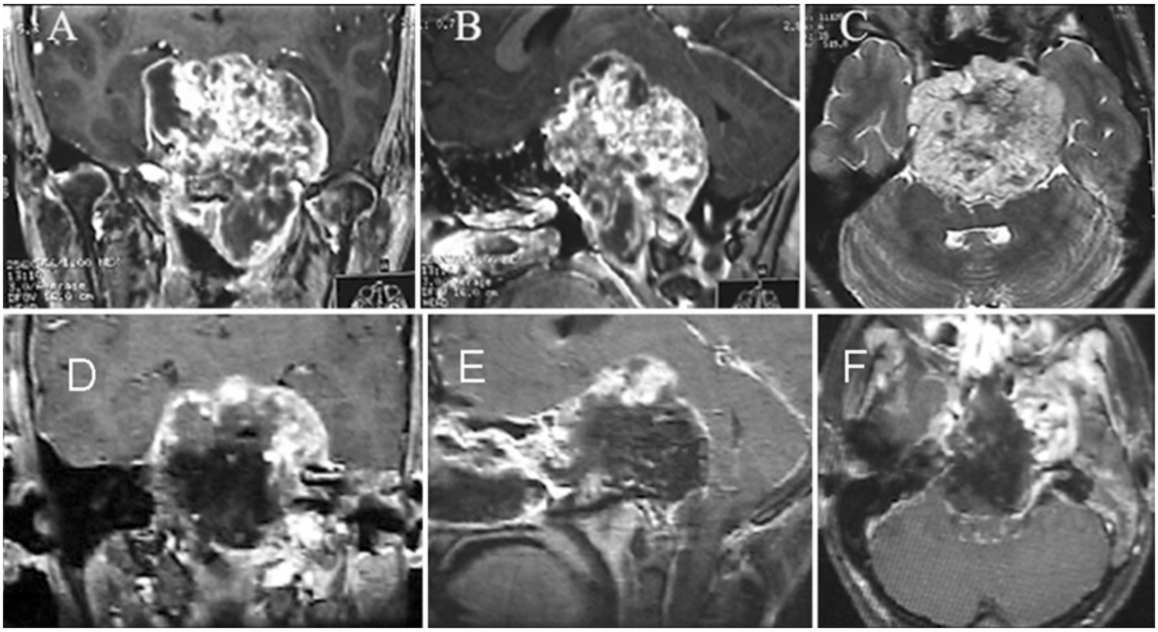

FIG. 7. Preoperative and postoperative T1-weighted MR images. A–C: Preoperative coronal, sagittal, and axial images showing a chordoma involving the entire clivus, with bilateral cavernous sinus involvement and impressive suprasellar and posterior displacement of the brainstem. D–F: Postoperative axial, sagittal, and coronal images demonstrating the adequate removal of the tumor located at the midline, and the lateral limitation of the approach.

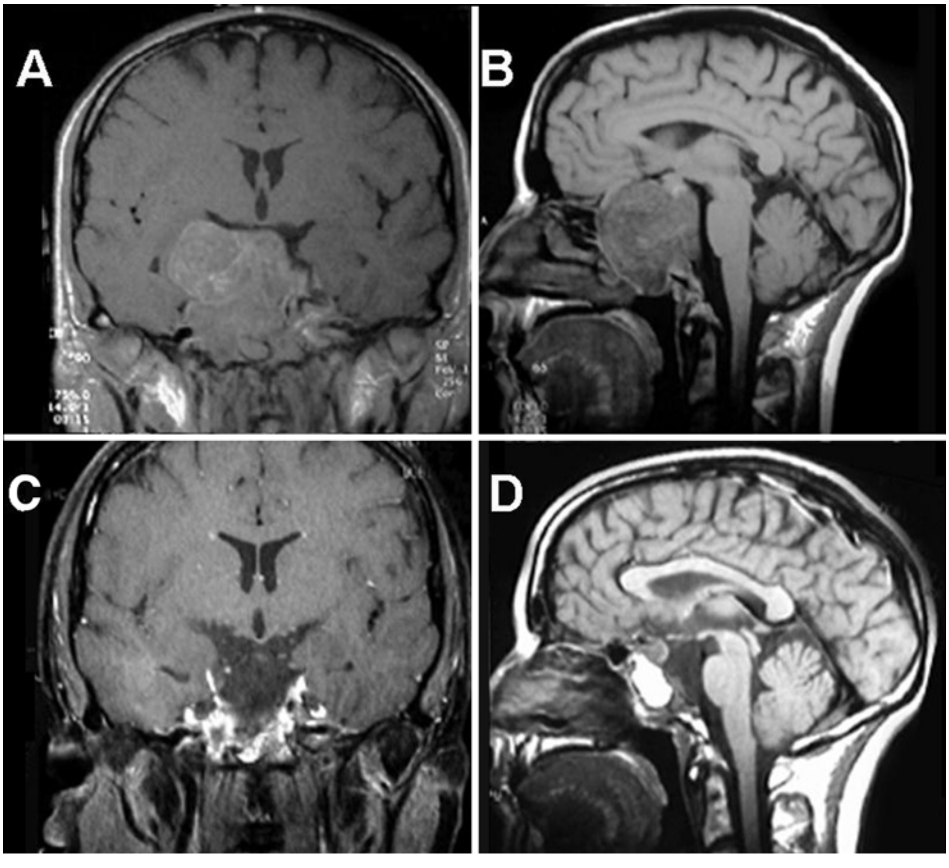

FIG. 8. A and B: Preoperative coronal and sagittal MR images revealing a large chordoma with suprasellar extension that will be grossly removed through the anterior clivectomy. C and D: Postoperative coronal and sagittal T1-weighted enhanced MR images depicting tumor.

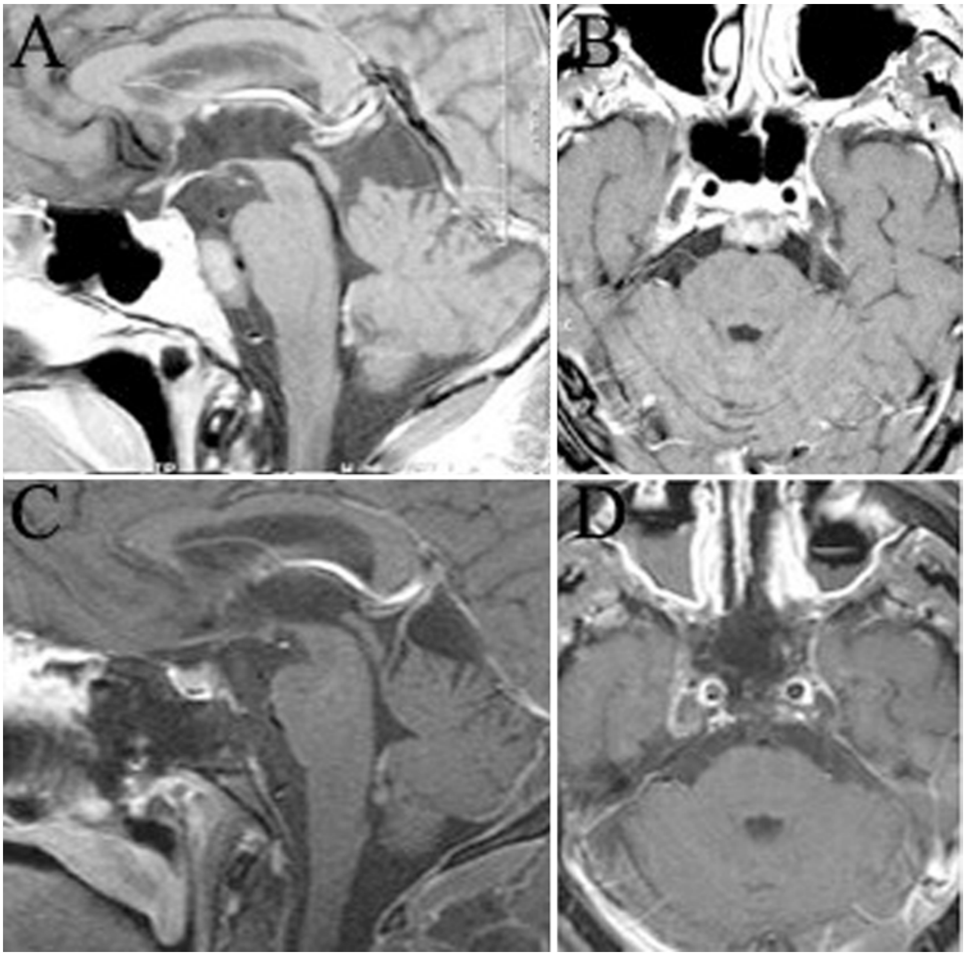

Fig. 9. Enhanced sagittal and axial T1-weighted MR images. A and B: Preoperative images revealing a chordoma behind the midclivus. C and D: Postoperative images showing the clival bone window after complete removal of the lesion.

Radiotherapy was performed in 26 of the 38 patients with chordoma. The recurrence rate in these patients after surgery and radiotherapy was 15%.

Discussion

All Old Roads Lead to the Clivus

The clivus has been divided into 3 subparts to facilitate the selection of the surgical approach.[11,47,58] The upper clivus corresponds to the basisphenoid bone, the region of the dorsum sella, which extends from the posterior clinoid process to the plane of the Dorello canal; the midclivus extends from the Dorello canal to the pars nervosa of the jugular foramen; and the lower clivus extends from the pars nervosa of the jugular foramen to the foramen magnum. These divisions are evident in the inner aspect of the clivus.[57] The outer aspect only displays the division between the middle and the lower clivus. The upper clivus corresponds to the posterior wall of the sphenoid sinus.

Based on these 3 parts and how the tumor involves the clivus, different surgical approaches can be selected and used to resect the tumor. These approaches can be grouped into 2 main categories: anterior and lateral. Anterior approaches to the clivus are the transoral,[1,12,15,29,40,50,60,61] transmaxillotomy,[1–3,6,7,9,11,30,47,51,52,56,69,71] transsphenoidal,[1,10,11,27,28,41–44,47] Le Fort I with maxillary drop down,[1,7,9,13,30,52,60] transfacial,[5,32,41,46,55,56,68] and transcranial–transbasal.[1,16,47,65] Accessing the clivus anteriorly dates back to 1919 when the transoral approach was used to remove a bullet.[38] This approach was later advocated by Scoville and Sharman[63] in 1951 and used extensively by Fang and Ong[20] for the treatment of infection of that area. Mullan et al.[53] were the first to describe the transoral–transclival approach for the treatment of an extraaxial tumor in 1966.

For removal of chordoma, Stevenson et al.[66] have described a transcervical approach made by entering the upper retropharyngeal space through a right upper cervical submandibular incision. Fox[22] has described the transcervical approach to basilar artery aneurysms. In 1987, Archer and colleagues[3] advocated the use of a Le Fort I maxillotomy as an approach to distal vertebral and midbasilar artery aneurysms, whereas Loyo et al.[49] used a maxillotomy to approach the cavernous sinus. All of these studies confirmed the appeal and the long-standing development of the anterior approaches. Our technique is a matter of steps toward its refinement in the era of minimally invasive surgery.

TABLE 2

*Preoperative clinical characteristics, clival involvement, tumor extension, & surgical outcome in 43 patients who underwent anterior clivectomy for tumor resection via an expanded transsphenoidal approach**

Case No.	Age (yrs), Sex	Dx	Location at the Clivus	Extension of Tumor	Preop Clinical Presentation	Approach-Related Complications
1	38, M	chordoma	upper, middle	lt cav sinus, SSS	headache, lt VI n	none
2	53, F	chordoma	upper, middle, lower	bilat cav sinus, sphenoid sinus	headache	none
3	41, F	chordoma	upper, middle	rt cav sinus	rt III n, rt VI n	none
4	13, F	chordoma	upper, middle	brainstem compression, sphenoid sinus	visual loss (lt), lt III, IV, VI & VIII	CSF leak (delayed) after RT
5	53, F	chordoma	upper	bilat cav sinus, SSS	visual loss (lt)	none
6	26, F	chordoma	middle, lower		lt VI, IX & X n	none
7	59, M	chordoma	upper, middle, lower	rt cav sinus	headache, visual loss (lt), lt IV,VI, IX, & X n	CSF leak
8	22, F	chordoma	upper, middle, lower	rt cav sinus, brainstem compression, sphenoid sinus		none
9	51, F	chordoma	upper, middle	rt cav sinus, SSS, none	headache, lt VI n	none
10	56, M	chordoma	upper, middle	lt cav sinus, brainstem compression, sphenoid sinus	headache, lt VI n	CSF leak (delayed) after RT
11	43, M	chordoma	upper, middle,	rt cav sinus	lt V & VI n	lt VI n (transient)
12	26, F	chordoma	upper, middle, lower	bilat cav sinus, sphenoid sinus		lt VI n (transient), rt VI n (permanent)
13	33, M	chordoma	upper, middle, lower	rt cav sinus, sphenoid sinus, parapharyngeal space, infratemporal fossa	rt V & rt VI n	none
14	51, F	invasive pituitary adenoma	upper, middle, lower	lt cav sinus, SSS, nasopharynx	bitemporal hemianopia	none
15	32, F	chordoma	middle, lower	brainstem compression	dizzness pain in rt ear	lt VI n (transient)
16	47, F	invasive pituitary adenoma	upper, middle	lt cav sinus, suprasellar region, sphenoid sinus		diabetes insipidus (transient)
17	12, M	chordoma	middle, lower	brainstem compression (C-2), prevertebral space	UE paresis, bilat IX, X, & XII n	CSF leak
18	26, F	chordoma	upper, middle, lower	SSS, brainstem compression	bitemporal hemianopia, lt VIII n	none
19	68, F	invasive pituitary adenoma	upper, middle	sphenoid sinus, brainstem compression	cervical & suboccpital pain	none
20	42, M	chordoma	upper, middle	brainstem compression	headache, lt V & VI n, bilat VII n	none
21	56, F	chordoma	upper	lt cav sinus, suprasellar brainstem compression	headache, lt V & VI n	none
22	23, F	chordoma	upper, middle	lt cav sinus, brainstem compression	ataxia, lt V & VI n	CSF leak
23	32, F	chordoma	upper, middle	sphenoid sinus	seizure	none
24	52, M	chordoma	upper, middle	brainstem compression	headache	none
25	30, M	chordoma	middle, lower	brainstem compression	headache, lt VI n	none
26	48, M	chordoma	upper, middle	lt cav sinus, brainstem compression	lt VI n	none
27	55, F	pituitary adenoma	upper, middle	suprasellar rt cav sinus	lt V n	none
28	31, F	chordoma	upper, middle	rt cav sinus, brainstem compression		none
29	40, M	chordoma	upper, middle	lt cav sinus, brainstem compression		none
30	29, F	chordoma	middle, lower	lt condyle, brainstem compression	lt VI, IX, X, & XII n	none
31	32, F	chordoma	upper, middle, lower	bilat cav sinus, suprasellar brainstem compression		none
32	47, M	chordoma	upper, middle	bilat cav sinus, suprasellar brainstem compression		none
33	61, F	chordoma	upper, middle, lower	brainstem compression	rt VI n	none
34	6, M	chordoma	upper, middle, lower	bilat cav sinus, brainstem compression, rt condyle	rt VI n	none
35	44, F	chordoma	upper, middle		rt VI n	none
36	52, F	pituitary adenoma	upper, middle	suprasellar lt cav sinus	headache	lt VI n (transient)
37	34, F	chordoma	upper, middle	lt cav sinus	headache	none

(continued)

TABLE 2 *(continued)*

*Preoperative clinical characteristics, clival involvement, tumor extension, & surgical outcome in 43 patients who underwent anterior clivectomy for tumor resection via an expanded transsphenoidal approach**

Case No.	Age (yrs), Sex	Dx	Location at the Clivus	Extension of Tumor	Preop Clinical Presentation	Approach-Related Complications
38	75, M	chordoma	upper, middle, lower	suprasellar cav sinus bilaterally, bilat occipital condyle	lt III n	none
39	76, M	chordoma	upper, middle, lower	cav sinus bilat		none
40	3.5, F	chordoma	upper, middle, lower	brainstem compression	bilat VI n	CSF leak
41	29, M	chordoma	upper	suprasellar rt cav sinus, sphenoid sinus		none
42	44, F	chordoma	middle, lower	brainstem compression		none
43	65, M	chordoma	upper, middle	suprasellar, rt cav sinus, rt petrous apex sphenoid sinus	rt V, VI, IX, & X n	rt hemiparesis (previous RT)

* cav = cavernous; n = nerve; RT = radiotherapy; SSS = suprasellar sphenoid sinus; UE = upper extremity.

Expanded Transsphenoidal–Skull Base Approach

Since its revival and refinement by Guoit and Thibaut[25] and Hardy and Wigser,[28] the microsurgical transsphenoidal route has become the favored route to pituitary lesions and recently has been used in association with endoscopic techniques.[18,31,35–37,43,57] Early on, Hardy and colleagues[27] and Laws[42] recognized the advantage of the anterior approach of the transsphenoidal route and promoted its use for suprasellar lesions other than pituitary lesions. Such use inspired the development of the extended transsphenoidal approach by the removal of the bone of the tuberculum sella and posterior planum sphenoidale between the optic canals with opening of the dura mater above the diaphragma. As delineated in 1987 by Weiss,[71] this approach and several innovative variations have been used to gain added exposure to cranial base and juxtasellar lesions.[11,31,47] The transsphenoidal approach has been used to remove clival chordomas by Guiot and Thibaut, Hardy and Wigser, Laws, and Weiss. Lesions arising from or involving the clivus such as chordoma are most often confined to the midline and frequently remain extradurally. They tend to extend in the anteroposterior direction.

Therefore, accessing these lesions via an anterior route has been correctly advocated.[1,11,12,31,43,44,47,71] This affords resection of the targeted lesions without opening the dura or exposing vital neurovascular structures. It also provides the most direct trajectory and allows minimal bone and soft-tissue dissection. Thus, direct visualization of the tumor in its rostrocaudal and side-to-side dimensions is readily achievable. Overall, this translates into a shorter interval for exposing the tumor compared with other approaches.

By adding uni- or bilateral medial maxillotomies to the traditional sublabial transsphenoidal approach, one creates a wider exposure, allowing the introduction and manipulation of various instruments, including a drill, without visual obstruction.

If the tumor extends laterally, a contralateral medial maxillotomy would allow placement of the retractor obliquely, which allows direct visualization of the tumor. Fraioli et al.[23] have described the bilateral removal of the anterior maxillary wall to expose and resect tumors involving the cavernous sinus in 11 patients. Adding the medial maxillotomy to the traditional transsphenoidal approach is a simple step requiring several additional minutes and posing minimal additional risks

Cerebrospinal Fluid Leakage

A CSF leak and subsequent meningitis are the main risk factors of the procedure. The absence of a vascularized tissue flap and the difficulty in obtaining a watertight dural closure are the underlying causes for these complications. Surgeons use any combination of the following: fascia lata, dural substitute, fat graft, fibrin glue, and/or placement of lumbar drain. To alleviate serious complications, we emphasize the placement of the graft intradurally, and then support it using an extradural fat and fibrin sealant. The integrity of intact nasal mucosa provides a vascularized support to the graft. We believe this has an advantage over transnasal disruption of the mucosa by a purely endoscopic approach, particularly because many of these patients will be subjected to radiotherapy that devascularizes the area tissue and is associated with delayed CSF fistulas.

Mobile-Head Neuronavigation

The absence of intraoperative shift has been a recognizable factor in the accuracy and reliability of neuronavigation in skull base surgery. Early in the treatment of patients in this series we realized the need to mobilize the head to provide different trajectories. Fixing the tracker to the skull or using the facemask tracer allows the surgeon to fully move a patient's head in various directions, thus achieving a better exposure of the entire region while maintaining the neuronavigation-based accuracy for localization and verification of structures.

Endoscopic-Assisted Techniques

Endoscopic surgery has flourished in the last decade with application beyond pituitary tumors. Numerous reports have addressed its advantages.[4,8,18,31,36,37,39,43,57] The senior author (O.A.) has routinely used the endoscope as a complement to the microscope, mainly because it allows the surgeon to look around blind anatomical corners that cannot be visualized directly with the microscope and because it affords a wide panoramic view,[4] hence taking full advantage of the endoscope as an "eye" in the depth of the field. We believe that with such tumors as described in this article and those that require extensive drilling and dissection, the combination of the microscope and endoscopic technique enhances the safety of the procedure and facilitates its undertaking.

Conclusions

A clivectomy via the expanded transsphenoidal approach—combined with the application of neuronavigation system to the mobilized head and the use of the endoscope—allows the surgeon to access different lesions involving the clivus and those situated anterior to the brainstem effectively and with minimal invasiveness.

The exposure and the surgical window created by this technique, to some extent, provide a similar window and wide exposure to the more extensive approaches such as the transfacial and Le Fort I techniques with maxillary dropdown. Although it employs the full benefit of endoscopic technique, it maintains the advantage of wide binocular exposure and the benefit of microsurgical techniques.

Disclaimer

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

References

1. Al-Mefty O, Borba LAB: Skull base chordoma: a management challenge. **J Neurosurg 86:**182–189, 1997
2. Anand VK, Harkey HL, Al-Mefty O: Open door maxillotomy for lesions of the clivus. **Skull Base Surg 1:**217–224, 1991
3. Archer DJ, Young S, Uttley D: Basilar aneurysms: a new transclival approach via maxillotomy. **J Neurosurg 67:**54–58, 1987
4. Batay F, Vural E, Karasu A, Al-Mefty O: Comparison of the exposure obtained by endoscope and microscope in the extended trans-sphenoidal approach. **Skull Base 12:**119–124, 2002
5. Biller HF, Shugar JMA, Krespi YP: A new technique for wide-field exposure of the base of the skull. **Arch Otolaryngol 107:**698–702, 1981
6. Bowles AP Jr, Al-Mefty O: The transmaxillary approach to the clival chordoma, in Al-Mefty O, Originato TC, Harkey HL (eds): **Controversies in Neurosurgery.** New York: Thieme, 1996, pp 115–122
7. Drommer RB: The history of the "Le Fort I osteotomy". **J Maxillofac Surg 14:**119–122, 1986
8. Catapano D, Sloffer C, Frank G, Pasquini E, D'Angelo VA, Lanzino G: Comparison between the microscope and endoscope in the direct endonasal extended transsphenoidal approach: anatomical study. **J Neurosurg 104:**419–425, 2006
9. Cocke EW, Robertson JH, Robertson JT, Crook JP: The extended maxillotomy and subtotal maxillectomy for excision of skull base tumors. **Arch Otolaryngol Head Neck Surg 116:**92–104, 1990
10. Conley J, Price JC: Sublabial approach to the nasal and nasopharyngeal cavities. **Am J Surg 138:**615–618, 1979
11. 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
12. Crockard HA: The transoral approach to the base of the brain and upper cervical cord. **Ann R Coll Surg Engl 67:**321–325, 1985
13. Crumley RL, Guttin PH: Surgical access for clivus chordoma. The University of California, San Francisco, experience. **Arch Otolaryngol Head Neck Surg 115:**295–300, 1989
14. Cushing H: Surgical experience with pituitary disorders. **JAMA 63:**1515–1525, 1914
15. Delgado TE, Garrido E, Harwick RD: Labiomandibular, transoral approach to chordomas in the clivus and upper cervical spine. **Neurosurgery 8:**675–679, 1981
16. Derome PJ: Surgical management of tumours invading the skull base. **Can J Neurol Sci 12:**345–347, 1985
17. Derome PJ, Guiot G: Surgical approaches to sphenoidal and clival areas, in Krayenbuhl H (ed): **Advances and Technical Standards in Neurosurgery, Vol 6.** Vienna: Springer, 1979, pp 202–236
18. de Divitiis OD, Conti A, Angileri FF, Cardali S, Torre DL, Tschabitscher M: Endoscopic transoral-transclival approach to the brainstem and surrounding cisternal space: anatomic study. **Neurosurgery 54:**125–130, 2004
19. Falcioni M, Taibah A, De Donato G, Russo A, Sanna M: [Lateral approaches to clivus.] **Acta Otorhinolaryngol Ital 17 (Suppl):**3–16, 1997 (Italian)
20. Fang HSY, Ong GB: Direct approach to the upper cervical spine. **J Bone Joint Surg 44:**1588–1604, 1962
21. Fisch U: Infratemporal fossa approach for lesions in the temporal bone and base of the skull. **Adv Otorhinolaryngol 34:**254–266, 1984
22. Fox JL: Obliteration of midline vertebral artery aneurysms via basilar craniectomy. **J Neurosurg 26:**406–412, 1967
23. Fraioli B, Esposito V, Santoro A, Lannetti G, Guiffre R, Cantore G: Transmaxillosphenoidal approach to tumors invading the medial compartment of the cavernous sinus. **J Neurosurg 82:**63–69, 1995
24. George B, Guihaume L: Anterolateral and posterolateral approaches to the foramen magnum: a technical description and experience from 97 cases. **Skull Base 5:**9–19, 1995
25. Guiot G, Thibaut B: [Extirpation of pituitary adenomas by trans-sphenoidal route.] **Neurochirurgia (Stuttg) 1:**133–150, 1959 (Fr)
26. Halsted AE: Remarks on the operative treatment of tumors of the hypophysis (two cases operated on by an oro-nasal route). **Surg Gynecol Obstet 10:**494–502, 1910
27. Hardy J, Grisoli F, Leclercq TA, Marino R: Transphenoidal approaches to tumors of the clivus. **Neurochirurgie 23:**287–297, 1977
28. Hardy J, Wigser SM: Transsphenoidal surgery of the pituitary fossa tumors with televised radiofluoroscopic control. **J Neurosurg 23:**612–619, 1965
29. Harris JP, Godin MS, Krekorian TD, Alksne JF: The transoropalatal approach to atlantoaxial-clival region: consideration for the head and neck surgeon. **Laryngoscope 99:**467–474, 1989
30. James D, Crockard HA: Surgical access to the base of skull and upper cervical spine by extended maxillotomy. **Neurosurgery 29:**411–416, 1991
31. Jane JA Jr, Thapar K, Kaptain GJ, Maartens N, Laws ER Jr: Pituitary surgery: transsphenoidal approach. **Neurosurgery 51:** 435–444, 2002
32. Janecka IP, Nuss DW, Sen CN: Facial translocation approach to the cranial base. **Acta Neurochir Suppl (Wien) 53:**193–198, 1991
33. Janecka IP, Nuss DW, Sen CN: Midfacial split for access to central base. **Acta Neurochir Suppl (Wien) 53:**199–203, 1991
34. Janecka IP, Sen CN, Sekar LN, Arriga M: Facial translocation: a new approach to the cranial base. **Otolaryngol Head Neck Surg 103:**413–419, 1990
35. Jho HD, Ha HG: Endoscopic endonasal skull base surgery:

part 1–the midline anterior fossa skull base. **Minim Invasive Neurosurg 47:**1–8, 2004
36. Jho HD, Ha HG: Endoscopic endonasal skull base surgery: part 2–the cavernous sinus. **Minim Invasive Neurosurg 47:** 9–15, 2004
37. Jho HD, Ha HG: Endoscopic endonasal skull base surgery: part 3–the clivus and posterior fossa. **Minim Invasive Neurosurg 47:**16–23, 2004
38. Kanavel AB: Bullet located between the atlas and the base of the skull: technique for removal through the mouth. **Surg Clin Chicago 1:**361–366, 1919
39. Kassam A, Thoms AJ, Snyderman C, Carrau R, Gardner P, Mintz A, et al: Fully endoscopic expanded endonasal approach treating skull base lesions in pediatric patients. **J Neurosurg 106 (2 Suppl):**75–86, 2007
40. Kennedy DW, Papel ID, Halliday M: Transpalatal approach to skull base. **Ear Nose Throat J 65:**125, 127–133, 1986
41. Lalwani AK, Kaplan MJ, Gutin PH: The transsphenoethmoid approach to the sphenoid sinus and clivus. **Neurosurgery 31:** 1008–1014, 1992
42. Laws ER: Transsphenoidal surgery for tumors of the clivus. **Otolaryngol Head Neck Surg 92:**100–101, 1984
43. Laws ER, Kanter SA, Jane JA Jr, Dumont AS: Extended transsphenoidal approach. **J Neurosurg 102:**825–828, 2005
44. Laws ER: Transsphenoidal surgery for chordomas and chondrosarcomas, in Harsh G (ed): **Neurosurgery of Complex Tumors and Vascular Lesions.** New York: Thieme, 2003, pp 106–113
45. Laws ER Jr: Transsphenoidal microsurgery in the management of craniopharyngioma. **J Neurosurg 52:**661–666, 1980
46. Lawton MT, Beals SP, Joganic EF, Han PP, Spetzler RF: The transfacial approaches to midline skull base lesions: a classification scheme. **Op Tech Neurosurg 2:**201–217, 1999
47. Liu KJ, Decker D, Schaefer SD, Moscatello AL, Orlandi RR, Weiss MH, et al: Zones of approach for craniofacial resection: minimizing facial incisions for resection of anterior cranial base and paranasal sinus tumors. **Neurosurgery 53:**1126–1137, 2003
48. Loeb HN (ed): **Operative Surgery of the Nose, Throat, and Ear.** St Louis: CV Mosby, 1917, Vol 2, pp 131–142
49. Loyo M, Sanchez Marle JD, Del Valle R, Mares M: The transnasal approaches to cavernous sinus, in Dolenc VV (ed): **The Cavernous Sinus.** Vienna: Springer-Verlag, 1987, pp 397–403
50. Menezes AH, Van Gilder JC: Transoral-transpharyngeal approach to the anterior craniovertebral junction: 10 years experience with 72 patients. **J Neurosurg 69:**895–903, 1988
51. Miller RH, Woodson GE, Neely JG, Murphy EC: A surgical approach to chordomas at the base of the skull. **Otolaryngol Head Neck Surg 90:**251–255, 1982
52. Moloney F, Worthington P: The origin of Le Fort I maxillary osteotomy: Cheever's operation. **J Oral Surg 39:**731–734, 1981
53. Mullan S, Naunton R, Hekmat-Panah J, Vailati G: The use of anterior approach to ventrally placed tumors in the foramen magnum and vertebral column. **J Neurosurg 24:**536–543, 1966
54. Nagib MG, Wisiol ES, Simonton SC, Levinson RM: Transoral labiomandibular approach to bassiooccipit chordomas in childhood. **Childs Nerv Syst 6:**126–130, 1990
55. Ogilvy CS, Barker FG II, Joseph MP, Cheney ML, Swearingen B, Crowell RM: Transfacial transclival approach for midline posterior circulation aneurysms. **Neurosurgery 39:**736–742, 1996
56. Price JC: The midfacial degloving approach to the central skull-base. **Ear Nose Throat J 65:**174–180, 1986
57. Puxeddu R, Lui MWM, Chandrasekar K, Nicolai P, Sekar L: Endoscopic -assisted transcolumellar approach to the clivus: an anatomical study. **Laryngoscope 112:**1072–1078, 2002
58. Rabadán A, Conesa H: Transmaxillary-transnasal approach to anterior clivus: microsurgical anatomical model. **Neurosurgery 30:**473–482, 1992
59. Samii M, Knosp E (eds): **Approaches to the Clivus.** Berlin: Springer-Verlag, 1992
60. Sandor GK, Charles DA, Lawson VG, Tator CH: Transoral approach to nasopharynx and clivus using the Le Fort I osteotomy with midpalatal split. **Int J Oral Maxillofac Surg 19:** 352–355, 1990
61. Sano K, Jinbo M, Saito I: [Vertebro-basilar aneurysms, with special reference to the transpharyngeal approach to basilar artery aneurysm.] **No To Shinkei 18:**1197–1203, 1966 (Jpn)
62. Schloffer H: Zur Frage der Operationen an der Hypophyse. **Beitr Klin Chir 50:**767–817, 1906
63. Scoville WB, Sharman IJ: Platybasia, report of ten cases with comments on familial tendency, a special diagnostic sign and end results of operation. **Ann Surg 133:**469–502, 1951
64. Sen CN, Sekhar LN: The subtemporal and preauricular infratemporal approach to intradural structures ventral to the brain stem. **J Neurosurg 73:**345–354, 1990
65. Sekhar LN, Nanda A, Sen CN, Snyderman CN, Janecka IP: The extended frontal approach to tumors of the anterior, middle and posterior skull base. **J Neurosurg 76:**198–206, 1992
66. Stevenson GC, Stoney RJ, Perkins RK, Adams JE: A transcervical transclival approach to the ventral surface of the brain stem for removal of a clivus chordoma. **J Neurosurg 24:** 544–551, 1966
67. Swearingen B, Joseph M, Cheney M, Ojemann RG: A modified transfacial approach to the clivus. **Neurosurgery 36:** 101–105, 1995
68. Tapia Acuña R: Juvenile naspharyngeal fibroma. **Ann Otol 90:** 420–422, 1981
69. Uttley D, Moore A, Archer DJ: Surgical management of midline skull-base tumors: A new approach. **J Neurosurg 71:** 705–710, 1989
70. Van Loveren HR, Fernandez PM, Keller JT, Tew JM Jr, Shumrick K: Neurosurgical application of Le Fort I-type osteotomy. **Clin Neurosurg 41:**425–443, 1994
71. Weiss MH: Transnasal transsphenoidal approach, in Apuzzo MLJ (ed): **Surgery of the Third Ventricle.** Baltimore: Williams & Wilkins, 1987, pp 476–494

Manuscript submitted April 17, 2007.
Accepted February 21, 2008.
Address correspondence to: Ossama Al-Mefty, M.D., 4301 West Markham #507, Little Rock, Arkansas 72205. email: keelandamye@uams.edu.