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Anterior Transpetrosal-Transtentorial Approach for Sphenopetroclival Meningiomas: Surgical Method and Results in 10 Patients

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This report presents a new surgical method and the results in 10 patients with petroclival meningiomas extending into the parasellar region (sphenopetroclival meningiomas). Minimal but effective extradural resection of the anterior petrous bone via a middle fossa craniotomy offered a direct view of the clival area with preservation of the temporal bridging veins and cochlear organs. The dural incision was extended anteriorly to Meckel's cave, and in cases with invasion of the cavernous sinus, Parkinson's triangle was enlarged by mobilization of the trigeminal nerve. This approach offered an excellent view from the mid-clivus to the cavernous sinus. Extra- as well as intradural tumor masses and dural attachments could be cleared under direct view of the pontine surface. The risk of injury to the lower cranial nerve and of retraction damage to the temporal lobe and brain stem were kept minimal by this approach. Total tumor resection was achieved in 7 patients, with no resultant mortality. Eight patients had a satisfactory postsurgical course, extraocular paresis being their main complaint. The extent of tumor resection depended on the degree of tumor adhesion to the carotid artery, and operative morbidity on the degree of tumor invasion of the brain stem. Of the 3 patients in whom subtotal tumor removal was achieved, only one experienced regrowth of the tumor and underwent a second operation during the follow-up period (6 months–6 years). (*Neurosurgery* 28:869–876, 1991)

Key words: Cavernous sinus, Clivus, Cranial nerves, Meningioma, Operative approach, Posterior cranial fossa, Transpetrosal approach

INTRODUCTION

One of the characteristics of meningiomas attached to the petroclival borderline where the sphenoid, petrous, and clival bones meet is a wide attachment extending over two or more of these sites (27). In our experience, tumors arising medial to the trigeminal nerve commonly extended in three directions: to the posterior fossa, the cavernous sinus, and the extradural space around the petrosal apex, including Meckel's cave. Therefore, excision of such tumors may remain incomplete, even if the subdural part of the tumor is removed.

The subtemporal-transtentorial approach (25, 26) offers a wide surgical field encompassing the upper clivus and parasellar area, but in which the petrous ridge obscures the surgical view behind the petrous bone. A common disadvantage of this approach has been damage to the temporal lobe caused by retraction, particularly if the venous drainage is interrupted (25, 27). With the lateral suboccipital approach (19, 27), the parasellar portions of the tumor cannot be reached, and the access route is surrounded by the lower cranial nerves. The presigmoid transpetrosal-transtentorial approach (1, 7, 8, 10, 17) offers the possibility of removing basal invasive lesions; however, the disadvantages of this approach include postoperative hearing disturbance and the risk of cerebrospinal fluid rhinorrhea. The purpose of this report is to present and discuss the results of the anterior transpetrosal-transtentorial approach.

SURGICAL TECHNIQUE

All procedures were carried out with the patient in the supine position, with a pad placed under the shoulder, keeping the upper body elevated 25 degrees to minimize venous bleeding. The head is placed laterally and fixed in the head holder. The scalp incision is made around the ear, and the anterior line is planned to spare the upper facial nerve and to create a craniotomy more anterior than that of the middle fossa approach for acoustic tumor surgery (16, 24) (Fig. 1*A*). The temporal muscle is dissected from the skull preserving a pedicle long enough to cover the drilled petrous bone on closure. The craniotomy is centered a little above the mandibular joint, and the lowest part of the squamous temporal bone is removed with rongeurs, until the cranial window is nearly flush with the floor of the middle fossa. It is unnecessary to expose or cut the sigmoid sinus, and if possible, mastoid air cells should not be opened. The dura of the middle fossa base is peeled from the skull until the petrous ridge is identified. The middle meningeal artery must be interrupted after coagulation, to allow manipulation near the foramen spinosum. It is easier to expose the anterior petrous bone, located beyond the eminentia arcuata, when the axis of the microscope is deviated anteriorly.

The major petrosal groove is one of the landmarks of the lateral margin of the anterior petrous bone. The greater superficial petrosal nerve, wrapped by a band of soft tissue, courses on it between the sphenopetrosal fissure and the hiatus facialis. Occasionally it has to be cut, in order to spare the facial nerve from injury during dural dissection. The eminentia arcuata, another surgical landmark, must not be opened if hearing is to be preserved. The area of drilling is surrounded by the trigeminal impression anteriorly, the eminentia arcuata posteriorly, the major petrosal groove laterally, and the carotid canal and internal auditory canal inferiorly. No organic structure will be damaged when bone resection is limited to within this area (Fig. 1*B*). The anterior pyramidal bone is usually of softer consistency than the middle ear bone, and this offers an important orientation during pyramid resection. Extradural parts of the tumor will appear in the course of bone resection.

After removal of the anterior pyramidal bone is completed, dural incisions are made above and below the superior petrosal sinus. Double Weck's clips are applied to the sinus, which is incised after clipping between the 5th and 7th nerves (Fig. 1*C*). Care must be taken to place the junction of the petrosal vein as far in the posterior part of the sinus as is possible. The tentorium is cut until the tentorial notch is opened.

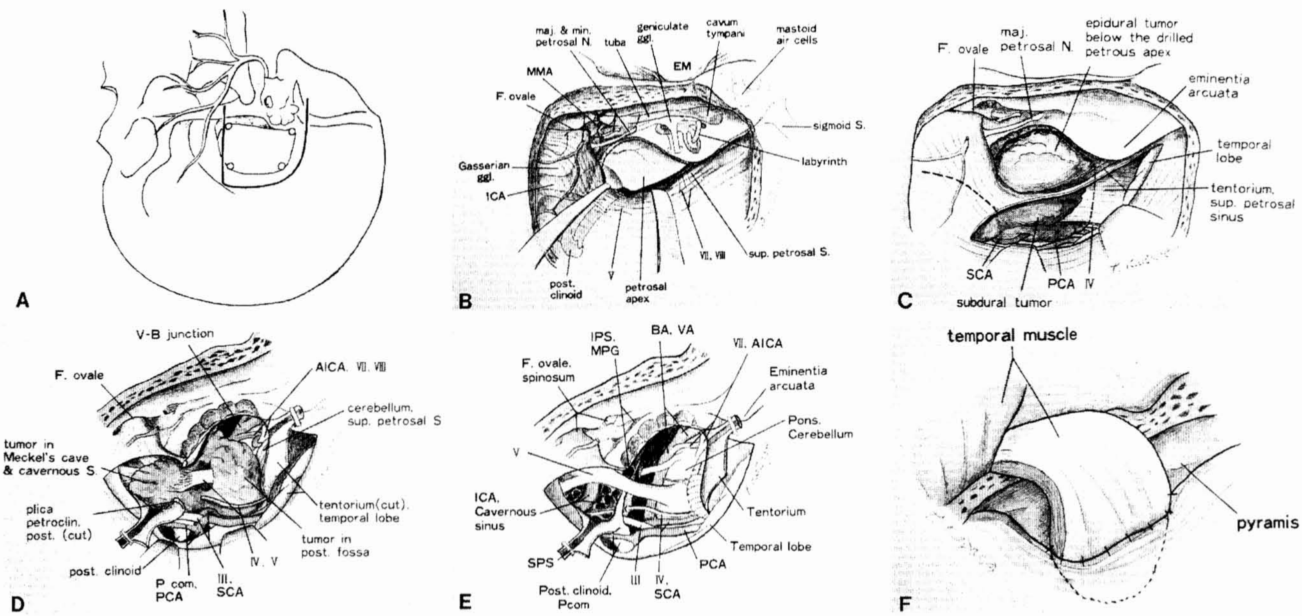

FIG. 1. Surgical illustrations of the anterior transpetrosal-transtentorial approach.

A, skin incision and site of craniotomy. A rectilinear incision is made anteriorly to spare the upper facial nerve. The craniotomy is centered low, above the mandibular joint.

B, extradural exposure of the petrous bone. Auditory structures and parasellar organs are superimposed on the surgical view. A *dotted line* indicates the area of bone resection. *EM*, external auditory meatus; *MMA*, middle meningeal artery; *ICA*, internal carotid artery.

C, dural incision. The middle fossa dura is opened parallel to the superior petrosal sinus, and the tentorium is cut along the posterior margin of the tumor (*right dotted line*). The *left dotted line* indicates a dural incision for parasellar overview. *SCA*, superior cerebellar artery; *PCA*, posterior cerebral artery.

D, opening of Meckel's cave and the cavernous sinus. The parasellar and posterior fossa parts of the tumor are visualized in a continuous surgical field. The trigeminal nerve can be mobilized to remove the tumor behind the nerve. *V-B*, vertebrobasilar; *AICA*, anterior inferior cerebellar artery; *Pcom*, posterior communicating artery.

E, surgical overview after tumor removal. An extensive view from the cavernous sinus to the clival area is obtainable. *SPS*, superior petrosal sinus; *IPS*, inferior petrosal sinus; *MPG*, major petrosal groove.

F, dural closure. A temporal muscle strip is used for covering both the petrous bone defect and the dural defect.

In cases where the tumor invades the tentorium, the incision is made along the posterior margin of the lesion. Bilateral retraction of the tentorial leaflets with sutures allows visualization of the posterior fossa.

The dural incision in the middle fossa is then extended anteriorly to expose the lateral wall of the cavernous sinus. The 5th nerve, commonly located at the lateral margin of the tumor, is dissected until its entry into Meckel's cave is identified. The dural band of plica petroclinoid posterior is cut with a scissors and the roof of Meckel's cave is opened. When the dural incision is extended along the 1st branch of the 5th nerve, the gasserian ganglion can be exposed entirely, reflecting the outer dural layer of the cavernous sinus. Between the cave and the cavernous sinus is an inner layer of dural sinus that is sometimes obscured by the tumor. Opening this layer exposes the tumor within the cavernous sinus (Fig. 1*D*). When the 5th nerve is retracted inferiorly, the tumor behind the gasserian ganglion can be removed from the enlarged Parkinson's triangle. The location of the carotid artery is detected with an ultrasonic Doppler probe. Sharp dissection is necessary around the carotid siphon, because the tumor within the posterior cavernous sinus is commonly of hard consistency and mixed with trabeculae of the sinus. The meningohypophyseal trunk, which arises from the medial loop of the internal carotid artery (ICA), must be interrupted, because it is a major artery feeding the tumor. During piecemeal removal of the tumor, venous bleeding from the cavernous sinus is controlled by plugging with Oxycel cotton balls. When the cotton ball is inserted into the inferior petrosal sinus, one of the main drainers of the cavernous sinus, care must be taken with the 6th nerve, which passes through that area.

After decompression of the tumor, the dural attachment is dissected from the clival bone, and the dural wall of the inferomedial triangle of the cavernous sinus is removed with the anterior leaflet of the tentorium (5). Complete tumor removal offers an extensive view from the cavernous sinus to the prepontine cistern. (Fig. 1*E*). The cavernous sinus as well as the petrous bone defect are coated with fibrin glue. In cases in which there are large air cells, muscle is packed into the cells and covered with a temporal muscle strip. The margin of the dural defect is then sutured to the fascia of the muscle strip (Fig. 1*F*). The bone flap is replaced and closure is performed in the usual fashion.

SURGICAL CASES

The anterior transpetrosal approach has been applied at our institution since 1980 in 10 cases of petroclival meningiomas, 4 epidermoid or dermoid tumors, and 5 basilar trunk aneurysms. All 10 meningiomas arose medially from the 5th nerve and extended into the parasellar region. The clinical data are summarized in Table 1. There were 8 women, and 2 men. In each patient, the preoperative diagnosis was obtained by computed tomographic (CT) and/or magnetic resonance imaging (MRI) scans. In 7 patients, the tumor attachment was found to be on the upper clivus (inferomedial triangle of the cavernous sinus) (5), extending into the parasellar region. In 2 others, the tumor was believed to originate in Meckel's cave. The remaining patient had an tumor of the intracavernous sinus that had initially been operated on 2 years previously, via the orbitozygomatic approach, but which had recurred and was protruding into the posterior fossa. The size of the tumors varied from 15 to 60 mm.

In each patient, the area of tumor extension was carefully evaluated preoperatively with CT scans, including the bone window technique, and MRI scans. Meckel's cave and the cavernous sinus were involved in 9 patients. The apical petrous bone was found to be eroded or invaded by an epidural extension of the tumor in 7 patients, 2 of whom showed even more extensive invasion into the sphenoid sinus or the orbit. In 4 patients, posterior extension of the process around the internal auditory meatus was observed. The most common symptoms were double vision, caused primarily by unilateral abducens nerve palsy (5 cases) or by multiple extraocular nerve palsies. Five patients complained of facial hypesthesia or paresthesia, and 2 of hearing disturbance; however, one of the latter had a history of otitis media. One individual had multiple cranial nerve palsies, ranging from the 2nd to the 12th nerves, that were caused by tumor extension along the lower clivus. In 3 patients, peritumoral edema was demonstrated on CT or MRI scans; however, only one complained of cerebellar symptoms, and none of these showed long tract signs.

SURGICAL FINDINGS

Details of the surgical findings in each patient are summarized in Table 2 and illustrated in Figure 2. The trigeminal nerve was encased by the tumor in 8 patients. Tumor invasion into Meckel's cave was prominent, scattered among the 5th nerve fibers that spread out in multiple directions (Fig. 3). These had to be sacrificed in four patients. The trochlear and abducens nerves were also commonly encased by the tumor in the posterior fossa or in the cavernous sinus (8 and 5 cases respectively). These tiny nerves were vulnerable, especially at their dural entrance, and were difficult to preserve when the tumor was of firm consistency. The 6th nerve was anatomically preserved in 6 patients, the 4th only in 3. In contrast, the oculomotor nerve was less commonly found to be encased (3 cases), and could be preserved in all instances except one, in which the tumor originated in close proximity to this nerve. In cases of tumor extension into the cavernous sinus, the ICA was displaced anteromedially; the medial loop was involved in 7 patients. In 4 of these, the ICA was firmly encased by the tumor. The meningohypophyseal trunk was prominent on angiograms of these patients, and the tentorial branch was a common feeder of the tumors (Fig. 4).

Total tumor removal, including the dural attachment, was achieved in 7 patients (Fig. 5). In 3 patients who had ICA encasement or further extension along the lower clivus, radical removal was not attempted because of the high surgical risk. In 4 patients in whom the size of the tumor exceeded 4 cm, the superior cerebellar artery (SCA) and anterior inferior cerebellar artery (AICA) were involved by the tumor at their proximal segments. A dense adhesion between the tumor and the pontine surface existed in these patients. The pial membrane was found already destroyed, and dissection caused damage to the pontine surface. These patients had evidence of peritumoral edema on their preoperative CT or MRI scans. Histopathological study furnished evidence of nine meningotheliomatous and one anaplastic meningioma.

POSTOPERATIVE COURSE

In the immediate postoperative course, 6 patients had good recovery, with no neurological problems other than unilateral cranial nerve

TABLE 1
Clinical Data in 10 Surgical Cases

Case	Patient Age (yr)/ Sex	Preoperative Symptoms	Tumor Size (cm)	Tumor Extension[a] Epidural MC	CS	PA	EX	Subdural UC	LC	TE	CPA	Perifocal Edema
1	38/M	Extraocular palsy (right 3rd nerve)	1.5	−	+	−	−	+	−	−	−	−
2	50/F	Double vision (right 6th nerve)	2.0	+	−	−	−	+	−	+	−	−
3	47/F	Double vision (right 4th and 6th nerves)	2.5	+	+	+	−	+	−	−	−	−
4	62/F	Headache	2.5	+	+	−	−	+	−	+	−	−
5	49/F	Double vision (right 6th nerve)	2.5	+	+	+	−	+	−	−	−	−
6	66/M	Double vision (left 6th nerve), left facial hypesthesia, hearing disturbance[b]	3.0	+	+	+	−	+	−	+	−	−
7	58/F	Ataxia, right facial hypesthesia	4.0	+	+	+	−	+	−	+	+	+
8	67/F	Double vision (left 6th nerve), right facial hypesthesia, tinnitus	4.0	+	+	+	−	+	−	+	+	+
9	57/F	Double vision (right 3rd, 4th, and 6th nerves), right facial hypesthesia	4.5	+	+	+	+	+	+	+	+	+
10	59/F	Multiple cranial nerve palsies[c] (left 2nd to 12th nerves)	6.0	+	+	+	+	+	+	+	+	−

[a] MC, Meckel's cave; CS, cavernous sinus; PA, petrosal apex; EX, extracranial; UC, upper clivus; LC, lower clivus; TE, tentorium; CPA, cerebellopontine angle. +, involved by tumor; −, not involved by tumor.
[b] History of otitis media.
[c] Parasellar tumor regrowth.

TABLE 2
Surgical Findings and Results in 10 Cases

Case	Brain Stem[a] Adhesion	Pial Destruction	Involvement of Cranial Nerves[b] 3	4	5	6	7–8	Involvement of Arteries[b] ICA	SCA	AICA	Pathological Type and Consistency of Tumor	Surgical Excision
1	−	−	E								Meningotheliomatous, hard	Total
2	−	−		T	E	T			T		Meningotheliomatous, soft	Total
3	−	−	T	ES	E	T			T		Meningotheliomatous, mixed	Total
4	+	+	T	ES	T	T		T	T		Meningotheliomatous, mixed	Total
5	−	−	T	ES	E	ES		E	T		Meningotheliomatous, mixed	Total
6	+	−	T	ES	ES	ES		T	T		Meningotheliomatous, hard	Total
7	+	+	T	ES	ES	T		T	ES	T	Meningotheliomatous, hard	Total
8	+	+	T	E	E	E		E	E		Meningotheliomatous, mixed	Subtotal
9	+	+	ES	ES	ES	ES	T	E	T	T	Meningotheliomatous, mixed	Subtotal
10	+	+	E	ES	ES	ES	T	E	E	E	Anaplastic, mixed	Subtotal

[a] +, present; −, absent.
[b] E, encased by the tumor; ES, encased by the tumor and surgically sacrificed; T, touched by the tumor.

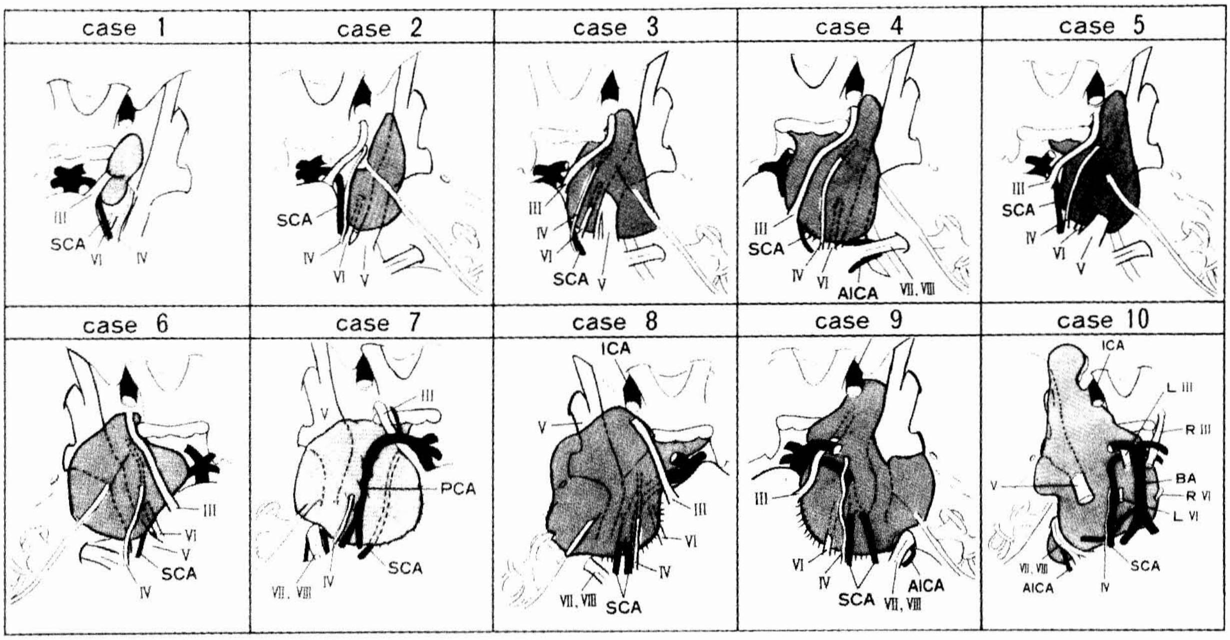

FIG. 2. Location of the tumors relative to the cranial nerves and arteries. *ICA*, internal carotid artery; *BA*, basilar artery; *SCA*, superior cerebellar artery; *AICA*, anterior inferior cerebellar artery.

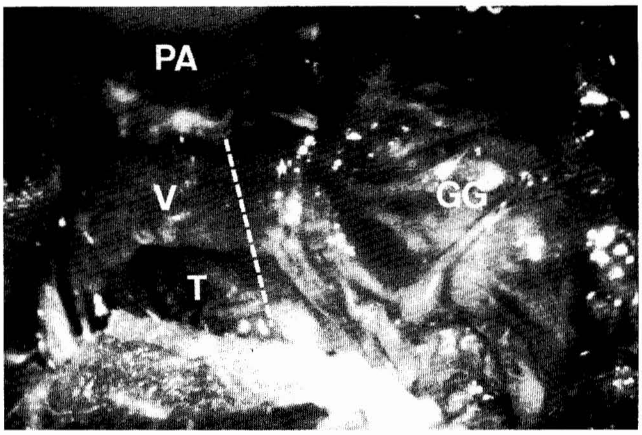

FIG. 3. Case 7, surgical view. The trigeminal nerve (*V*) was involved in the tumor (*T*). The nerve fibers of the gasserian ganglion (*GG*) are separated by the tumor. A *dotted line* indicates the orifice of Meckel's cave. *PA*, petrosal apex.

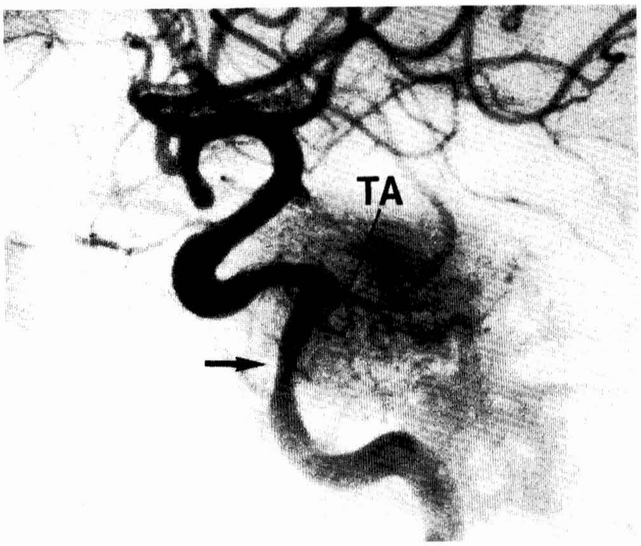

FIG. 4. Case 8, preoperative angiogram of the left carotid artery. Mild stenosis of the ICA (*arrow*) indicates carotid encasement by the tumor. *TA*, tentorial artery.

palsies. During the 2nd week there were no documented temporal lobe symptoms nor cerebellar signs, and most symptoms were related to palsies of the 3rd to 6th cranial nerves. In the 4 patients whose tumors were more than 4 cm in diameter, contralateral hemiparesis occurred postoperatively, accompanied by a temporary deterioration of consciousness. Two patients recovered favorably within a few weeks, but in the other 2, permanent hemiparesis remained as a consequence of brain stem infarction. No patient developed postoperative hearing disturbance or facial nerve palsy from resection of the pyramid. In one patient, cerebrospinal fluid rhinorrhea occurred, requiring surgical repair. Finally, in one patient, hydrocephalus developed progressively during the postoperative course, necessitating placement of a ventriculoperitoneal shunt.

Cranial nerve deficits and morbidity

The clinical results are presented in Table 3. During the early postoperative period, extraocular movement of the operated side worsened, but 3rd nerve function recovered completely within 2 months in 5 of the 7 patients whose nerves had been anatomically preserved; recovery of function was less favorable, however, for the 4th and 6th nerves. Function of the 6th nerve recovered in 4 of the 6 patients with anatomically preserved nerves, but one of them still complains of double vision caused by loss of function of the 4th nerve, which was sacrificed during surgery. The 4th nerve could be functionally preserved in only 3 patients. Another two individuals with multiple preoperative ocular nerve palsies related to large tumors sustained unilateral ophthalmoplegia after surgery.

Only one patient was free of preoperative extraocular paresis. Facial hypesthesia was caused in most cases by dissection of the 5th nerve, but was a less serious complaint compared with extraocular palsy, because it occurred mainly in the 1st and 2nd divisions. In 4 patients whose 5th nerve roots were sacrificed during surgery, mastication power decreased. No patient complained of facial pain after surgery.

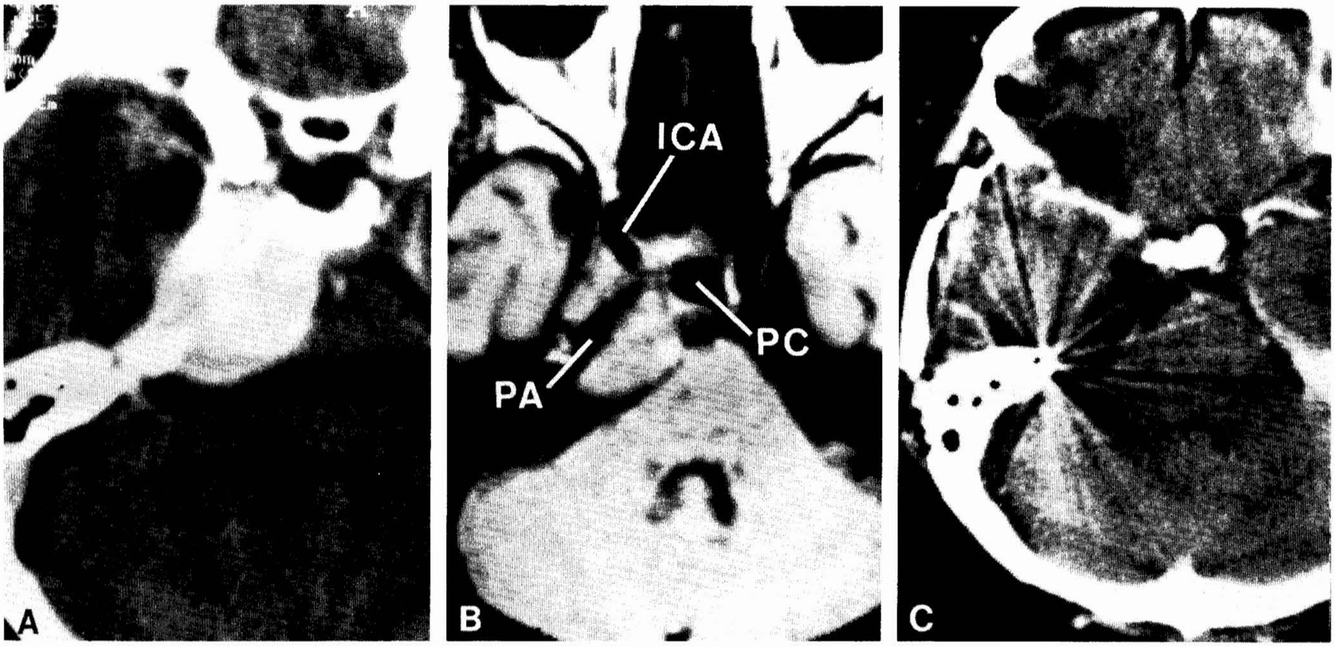

FIG. 5. Case 3. *A*, CT scan before surgery. *B*, MRI scan of the same section. The locations of the carotid artery (*ICA*) and petrous apex (*PA*) are clearly shown. *PC*, posterior clinoid. *C*, CT scan taken 14 days after surgery. The tumor has been totally removed.

TABLE 3
Postoperative Condition in 10 Patients

Case	KPS[a] (%)	Cranial Nerves[b] 2	3	4	5	6	7	8	9–12	Long Tract Signs	Surgical Complications
1	90		U							None	None
2	80				M	W				None	Facial hypesthesia
3	80			U	M	U				None	Facial hypesthesia
4	80			S	M					Temporary left hemiparesis	Double vision and facial hypesthesia
5	80			S	M	U				None	Facial hypesthesia
6	80		M	S	W	U	U			None	Mild ptosis and cerebrospinal fluid rhinorrhea (repaired)
7	30		M	S	U	M				Left hemiplegia	Brain stem infarction and hydrocephalus (ventriculoperitoneal shunt)
8	80				U	I		I		Temporary right hemiparesis	Small pontine infarction
9	70		U	U	U	U				Mild left hemiparesis	Small pontine infarction
10	60	U	U	U	U	U	U	U	I	Temporary right hemiparesis	Contralateral abducens palsy

[a] Karnofsky Performance Status 6 months after surgery.

[b] U, preoperative deficit, unchanged; I, preoperative deficit, improved; W, preoperative deficit, worsened; M, postoperative deficit, mild; S, postoperative deficit, severe.

As a consequence of severing the greater superficial petrosal nerve, ipsilateral lacrimation temporary decreased, but recovered within a few months. By 6 months after surgery, all but one of the patients was able to care for him- or herself. Seven could perform their household chores (Karnofsky Performance Status, 80–90%) (12), but two could not (Karnofsky Performance Status, 60–70%), because of mild hemiparesis or multiple cranial nerve palsies. Only one patient remained disabled (Karnofsky Performance Status, 30%), as a result of pontine infarction.

Follow-up data

Follow-up data were obtained in each patient between 6 months and 6 years postoperatively using contrast-enhanced CT and/or MRI scans performed twice a year (Table 4). Total tumor resection was demonstrated in 7 patients (Fig. 5). In one patient who had an anaplastic meningioma, postoperative radiation was effective, and the initial residual tumor has completely disappeared. Because of tumor regrowth, one patient underwent a second operation 4 years later; the postoperative result was poor, however, mainly because of adhesions around the brain stem. Surgical dissection resulted in brain stem infarction. In two other patients, residual parts of the tumor were detected around the carotid artery or on the lower clivus, but showed no significant increase in size. There was no mortality during the follow-up period.

DISCUSSION

Clival meningiomas have been reported as comprising from 5 to 38% of posterior fossa meningiomas (2, 6, 27). This disparity may be the result of differing criteria for a "clival meningioma." Past series have obviously included cerebellopontine angle meningiomas with medial extension. Additional detailed studies have reported that the majority of clival meningiomas originated near the region of the spheno-occipital synchondrosis (3, 8, 15, 27), and showed bidirectional extension into the posterior and the middle fossa (sphenopetroclival meningioma). All the meningiomas in our series arose between the medial and 5th nerves, with an epidural extension into the parasellar area, including the cavernous sinus, Meckel's cave, and the petrosal apex. It is noteworthy that even small or medium-sized tumors eroded or invaded the apical petrous bone. In previous reports, this finding has not been mentioned, because verification is possible only by MRI scan or by surgical resection of the petrous bone. Tumor invasion in this area is facilitated by the fact that the apical pyramidal bone is commonly softer than the compact part of the middle petrous bone. The complicated venous structures around the tumor bed, including the cavernous sinus, superior and inferior petrosal sinuses, and basilar plexus, may explain the extension of these tumors and constitute a significant difference from meningiomas of the cerebellopontine angle, which originate around the internal auditory meatus.

Therefore, the ideal access for radical surgery of these particular tumors should be a combination of an epidural and a subdural approach, with resection of the petrous bone, such as the transpetrosal approach. Hakuba and associates (7, 8) reported 8 cases of clival meningiomas that were totally or subtotally resected by the transpetrosal-transtentorial approach. This access allowed a more radical approach, concomitantly reducing the damage to the brain and cranial nerves caused by retraction. The pyramidal bone is widely resected, including the labyrinth and mastoid, with separation of the external auditory canal through a large suboccipital-temporal-pterional craniotomy. This wide surgical field might be of benefit in the resection of extremely large petroclival tumors with wide attachment covering the whole petrous bone. In our series of meningiomas of the cerebellopontine angle and acoustic neurinomas, wide resection of the pyramidal bone was employed, because hearing in these patients had already been lost before surgery (24). In patients with small or middle-sized petroclival meningiomas, however, there are commonly no lower cranial nerve signs before surgery, as we also found in this series. Resection of the posterior part of the pyramidal bone was essentially unnecessary in these patients. A local but effective resection of the anterior pyramidal bone offered enough exposure for microsurgical dissection when the lesion did not extend beyond the internal auditory meatus (11, 13, 14).

The advantages of a limited resection of the pyramidal bone are the following: 1) preserved auditory function, 2) reduced risk of cerebrospinal fluid leakage, and 3) shortened time of operation. The risk of other surgical complications, including injury to the facial nerve or lower cranial nerves, during resection of the petrous bone may also be reduced. Resection of the posterior petrous bone should be carried out in tumors that extend below the level of the internal auditory meatus.

Another advantage of this approach that is worthy of mention is the easy access it affords to the parasellar area in the surgical field. In cases of parasellar involvement, the tumor extended behind the gasserian ganglion, making surgical removal by the conventional subtemporal approach difficult. After resection of the apical pyramidal bone, the 5th nerve could be mobilized and Parkinson's triangle enlarged, resulting in the possibility of clearing the tumor from around the carotid siphon. This may be called "the posterior approach" to cavernous sinus lesions, in contrast with the anterior approach described by Dolenc (4) and Sekhar and Møller (20). The advantage of this posterior approach is that it possible to reach deeper into the posterior fossa through it than through the anterior approach, covering the upper two-thirds of the clivus. It should be noted, however, that the limit of this approach is reached when the tumor extends beyond the anterior loop of the carotid artery or when it spreads along the lower clivus. For extensive tumors including the whole cavernous sinus or the lower clivus (as our Cases 9 and 10), the combined approach (9, 21), or further resection of the petrous bone might be beneficial (23). In the future, arterial reconstruction may become an additional technique in cases with carotid encasement (22).

In reports prior to 1970, the surgical mortality of patients operated on for clival meningiomas was extremely high (27); it decreased to less than 20% after the development and application of microsurgical techniques (7, 15, 18, 27). According to these reports, tumor adhesion to the brain stem was the factor that most influenced morbidity. Complete dissection of the larger tumors in our series resulted in pontine infarction, the pial membrane of the brain stem being already destroyed and the pial vessels involved by the tumor. The presence of peritumoral edema on CT or MRI scans offered important prognostic information. In cases of small or medium-sized tumors, the possibility of postoperative cranial nerve deficits must be considered. In most patients, the 4th and 6th cranial nerves were encased by the tumor. Tumor masses within the posterior cavernous sinus were commonly firm, mixed with trabeculae of the sinus, and showed dense adhesion to those nerves. Tumors located in Meckel's cave frequently infiltrated the loose nerve fibers near the gasserian ganglion. These findings are completely different from those in cases of other benign tumors, such as neurinomas, chordomas, or pituitary adenomas and angiomas. It was rare that preoperative extraocular dysfunction (double vision) recovered after surgery, but in cases of such meningiomas, these nerves also had to be sacrificed, although much effort was undertaken to preserve them anatomically. In contrast, the 3rd nerve could be functionally preserved in most patients because it was not commonly encased by the tumor, but merely displaced by its upper margin. In cases of partial tumor resection to avoid postoperative cranial nerve deficits, tumor regrowth might require a second procedure. It should be emphasized that dense adhesions, the consequence of the first intervention, may significantly increase the surgical risk involved in a second operation, as we experienced in Case 5.

Our results suggest that it is most important to remove the tumor completely during the first operation, before carotid encasement or dense adhesions to the brain stem have oc-

TABLE 4
Neuroradiological Findings during the Follow-up Period

Case	Follow-up Period	Tumor
1	6 mo	Disappeared
2	2 yr, 1 mo	Disappeared, no regrowth
3	2 yr, 11 mo	Disappeared, no regrowth
4	4 yr, 9 mo	Disappeared, no regrowth
5	6 yr, 4 mo	Regrowth 4 years after surgery[a]
6	1 yr, 4 mo	Disappeared, no regrowth
7	6 mo	Disappeared
8	3 yr, 8 mo	Remained in the cavernous sinus, subclinical increase in size
9	3 yr, 6 mo	Remained in the cavernous sinus, no increase in size
10	4 yr, 6 mo	Disappeared, no regrowth[b]

[a] The patient underwent a 2nd operation.
[b] The patient received postoperative radiotherapy.

curred. We feel that complete removal can be achieved with minimal surgical risks by the anterior transpetrosal-transtentorial approach.

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COMMENTS

The technique of surgical removal of the petrous apex to access the posterior cranial fossa was first reported by Kawase et al. as an approach to aneurysms of the mid-basilar artery. In this article, they have discussed the use of this technique for excising meningiomas involving the cavernous sinus, Meckel's cave, and the upper and mid-clival area.

One of the problems in removing the petrous apex extradurally is that access is limited by the subtemporal dura. We have preferred to remove the petrous apex intradurally, after defining the landmarks in the middle cranial fossa extradurally. Meckel's cave is opened, and the trigeminal root and ganglion are rotated out of the way with a suture; the dura is excised over the petrous apex area to do this. This is combined with a posterolateral transcavernous approach to the upper clival tumor, as described by Sekhar et al. (2).

The lower limit of clival exposure by the removal of the petrous apex alone corresponds to a radiologically recognizable landmark, namely, the horizontal segment of the petrous ICA (2). This usually exposes the origin of the 7th and 8th cranial nerves, the anterior surface of the ipsilateral half of the pons, the 6th cranial nerve, about 1.5 cm of the basilar artery inferior to the trigeminal root, and the origin of the anterior inferior cerebellar artery (1). If further exposure is desired, a subtemporal and infratemporal approach is necessary, with displacement of the entire petrous ICA and further removal of the clival bone. This will allow the surgeon to reach as low as the hypoglossal foramen (4). All of these approaches through the medial petroclival bone are limited laterally by the facial nerve (labyrinthine segment) and the cochlea.

Major technical problems with meningiomas in this location are encasement of the intracavernous ICA, the basilar artery or its branches, and adhesions to the brain stem due to the absence of a subarachnoid plane. Tumors can sometimes be dissected from an encased intracavernous ICA, but complete excision usually requires replacement of the ICA with a saphenous vein graft (3). Tumor-encased basilar artery or branches can usually be dissected free, but occasionally, residual tumor may have to be left attached. When a subarachnoid plane is absent, tumors can still be dissected with patience and tedium; however, scar tissue from previous surgery or radiotherapy may make this impossible. Major morbidity in these operations is usually the result of occlusion of a branch of the basilar artery (2).

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Dr. Kawase and his colleagues eloquently describe a surgical modification of the extended middle fossa approach they have used for other lesions. Their innovation, thoroughness, and detailed reporting of their meningioma cases are commendable. They clearly differentiate sphenopetroclival meningiomas having attachments medial to the 5th nerve from other meningiomas having attachments on the posterior aspect of the petrous bone, a crucial differentiation having a significant impact on the surgical approach and outcome. They accurately determine that if a tumor has a large extension into the posterior fossa, their approach may yield unsatisfactory results. Because the window achieved by drilling the petrous apex is limited to about 1.5 cm, these findings should be expected. The petrosal approach, which we have used for these tumors, provides better exposure of large tumors (1). Additionally, the petrous apex is drilled through the petrosal approach, increasing the exposure of the attachment of petroclival meningiomas.

The high frequency of facial hypesthesia, which might lead to facial pain on longer follow-up, is of concern. A longer follow-up period to determine this outcome would be helpful. The authors advocate keeping the greater petrosal nerve intact. On the contrary, I believe it is safer to section this nerve sharply to avoid traction on the facial nerve and consequent facial nerve palsy. Sometimes, the petrous apex and petroclival junction might be areas of dural-venous lakes and the source of annoying bleeding. Our experience also differs from that of the authors with regard to the wide attachment of these meningiomas. We corroborate the original finding of Castellano and Ruggiero of a rather small attachment, despite a wide extent over the dura. The authors correctly state that the best chance for removing these meningiomas is during the first operation, and that the best outcome results when total removal is possible.

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