

Two-staged Keyhole Approach for Skull Base Tumors

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Abstract

Most of skull base tumors are conventionally approached by skull base technique. During a two-year period (1998-1999), seven skull base tumors comprised of 6 petroclival tumors and one anterior foramen magnum tumor were operated by a two-staged keyhole approach at Prasat Neurological Institute, Bangkok, Thailand. The patients' age range was 6-75 years. They were 5 males and 2 females. Total tumor removal was achieved in 4 cases. All patients except one which preoperatively bed ridden, showed improvement their neurological functions. There was no mortality except some morbidities; 2 brainstem ischemia which persisted in 1 case, 1 transient cranial nerve III deficit, and 1 cranial nerve V dysfunction that caused facial numbness. This 2-staged keyhole approach is an alternative approach for some skull base tumors and is a minimally invasive technique comparing to other approaches.

Key words : petroclival tumor, anterior foramen magnum tumor, keyhole approach, minimally invasive technique.

Currently, the skull-base technique is popularized and commonly performed for skull base lesions by a team of neurosurgeon, ENT surgeon and plastic surgeon. This surgical technique provides better exposure with greater illumination in the deep narrow surgical field. Since Prasat Neurological Institute is a specialized hospital, all type of surgical procedures are performed by neurosurgical staffs only. The skull base operations have been performed in our Department of Neurosurgery since 1993.

At the end of 1993, keyhole surgery was first performed in Prasat Neurological Institute. With the

recent development of enhanced minimally invasive technique, therefore the keyhole approach had been increasingly performed. As of the time of this report (December 1999) we have had more than one hundred cases of keyhole surgery. Due to our limitation of the teamwork for open approach in skull base surgery coupled with our increasing experience gained in the keyhole approach, more cases of skull base lesions were considered for keyhole approach whenever possible. For some lesions that were too large or not suitable for single keyhole approach, a staged keyhole approach from different corridors performing in

separate setting was employed - the so called two-staged key hole approach. Preliminary experience of the two-staged keyhole approach for some skull base tumors surgery is herein presented and its advantage and disadvantage are discussed.

PATIENTS AND METHODS

During the two-year period of 1998 to 1999, seven cases of skull base tumors underwent surgery by the two-staged keyhole approach. They were 5 males and 2 females, age between 6 - 75 years. The lesions were 6 petroclival tumors and one anterior foramen magnum tumor. These tumors were considered difficult or not possible by the single keyhole method. The criteria for two-staged keyhole approach are; (i) large skull base tumor involving two or more cranial fossae, (ii) mid line skull base tumor extending bilaterally not possible for single-staged keyhole approach method, and (iii) patients with significant or serious illness which may become unstable to undergo a lengthy operation. The two-staged operation is performed in different time settings to obtain the best positioning of the patient for each staged keyhole approach.

The plan for approaches in both stages is based on the findings obtained by MRI, CT scan and angiography. The scope of first staged operation must include the attempt of total tumor removal in one cranial fossa or one sided of tumor extension. The second staged approach will cover the remaining area. The second staged approach was scheduled after the patient was stable and the tumor histopathology had been reported. If the histopathology was benign, the remaining tumor will be attempted for total removal. In case of malignant tumor, the tumor will be removed as much as possible and not to risk for inadvertent complications. Radiotherapy and chemotherapy will be considered postoperatively according to tumor histopathology. Discussion was made with patient and members of family for their approval for the second stage keyhole approach.

Operative Technique

The keyhole concept and philosophy : If one looks through a keyhole of a door, one can see a large view of the room facing the door. The more distance from the keyhole, the wider view one can visualize. Therefore, if this keyhole effect is applied for intra-

cranial lesions with microsurgical technique, it will enable us to perform the operation through a small sized craniotomy. The deeper the lesions reflect the less necessary for a large craniotomy. Contrarily, the view close to the door is very limited, thus implies that keyhole surgery is unsuitable for the large superficial lesion. A keyhole surgery does not necessarily connote the size of craniotomy itself, but the craniotomy that is as small as possible or as large as necessary to allow successful surgery being performed.

Petroclival tumor

The petroclival lesions were approached initially by a subtemporal keyhole approach and then followed by the retromastoid keyhole approach.

Subtemporal keyhole approach

The patient was placed in supine position with a cushion support of the shoulder to promote the head rotation and to bring the zygoma in the horizontal plane. The head was shaved in a small area just above the zygoma and anterior to the tragus.

The subtemporal keyhole approach was done by simple vertical straight skin incision approximately 5 cm in length starting from the inferior rim of the zygomatic arch anteriorly toward the external auditory meatus. Then a small craniotomy 2 - 2.5 cm x 1 - 1.5 cm was made just above the root of the zygoma. Usually the base of the craniotomy had to be drilled more toward the temporal base to be adequate for minimal temporal lobe retraction. This subtemporal keyhole approach was best described in details by Taniguchi and Perneczky.²

The last few cases in this report were performed initially working with high-speed drill to create a small craniectomy at the zygomatic level downwards. Usually the area of the craniectomy about 1 - 1.5 x 2 cm was sufficient and the size may vary in individual cases. With this exposure the surgeon was able to identify the tumor in the tentorial space intradurally. The tumor was extirpated either by suction, cauterization, ultrasonic aspirator, in intracapsular piecemeal fashion. By this approach the goal was to totally remove the tumor in the supratentorium. In addition, some of the infratentorial tumor could also be removed by division of the tentorium at the entry point of cranial nerve IV. Caution must be strictly observed to avoid the cranial nerve IV injury during the division of the tentorium.

Bleeding from the petrosal sinus were controlled either by coagulation, surgical packing or clip application. After the supratentorial tumor was completely removed including some tissue of the infratentorial portion, closure was simply made.

Retromastoid approach

The patient was in three-quarter prone that brought the retromastoid part on the uppermost. This second, retromastoid approach, was performed via a post-auricular curvilinear incision starting about 2 cm above the level of uppermost ear pinna to the level of the digastric groove. The asterion and the occipito-mastoid suture correlate to the transition of transverse sinus to sigmoid sinus landmark. The craniectomy was made by high-speed drill to expose the area of the junction of the transverse sinus and the sigmoid sinus. The size of the craniectomy was tailored according to

the extension of the tumor. Through this intradural approach, one can work between the cranial nerves V and VII, and medially to the cranial nerve V. In every case of benign lesion, total tumor removal was attempted. The attempt for tumor removal was less aggressive when tumor specimen obtained from the first operation was malignant, tumor with evidence of brain stem invasion either on MRI or intra-operative view, tumor with adherence to major artery on brain stem or patient was in unstable condition due to medical illness. In the case achieving total tumor removal, the area approached by the first stage could be clearly identified. Closure of cranial wound was done in the usual technique.

Anterior foramen magnum tumor

Lateral foramen magnum approach: The patient was positioned in three-quarter prone. The foramen

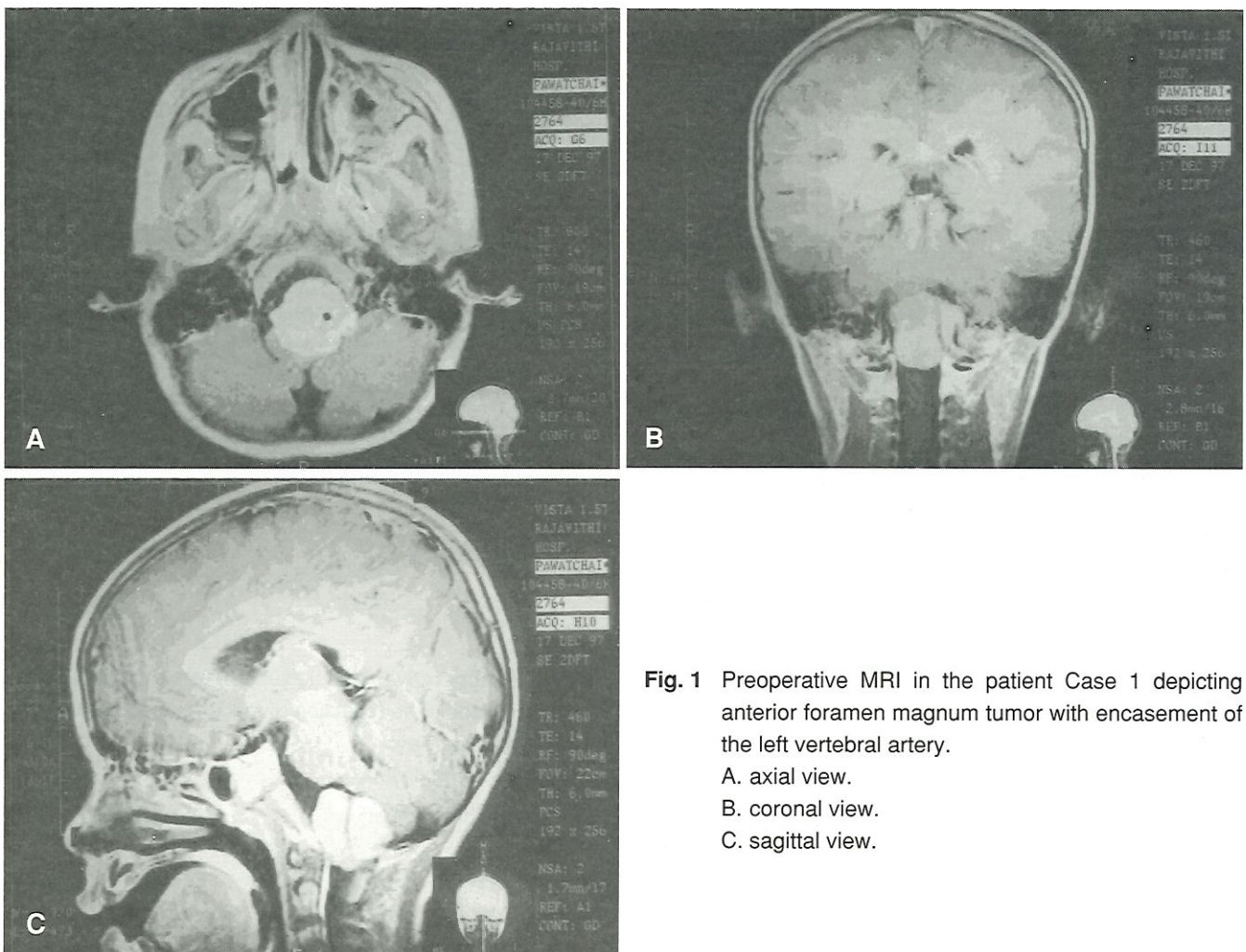


Fig. 1 Preoperative MRI in the patient Case 1 depicting anterior foramen magnum tumor with encasement of the left vertebral artery.

A. axial view.

B. coronal view.

C. sagittal view.

magnum was approached by drilling out the posterior lip on either side of the foramen magnum in an oval shape of about 2 x 2.5 cm in diameter. After the dural opening, CSF in the cisterna magna can be released and the cerebellum was retracted upwards exposing the lateral surface of the cervicomedullary junction. Following through this window medio-superiorly, the tumor at the anterior foramen magnum could be removed from both sides.

CASE REPORT

Patient 1. A 6 year-old boy suffered progressive weakness until eventually was unable to walk. Physical examination revealed quadriparesis of grade IV/V. CT scan and MRI revealed a well circumscribed tumor located in the mid line anterior to the foramen magnum. In addition, MRI also revealed that the left

vertebral artery was encircled by the tumor. The first stage was approached on the right side of the foramen magnum. Intra-operatively, the tumor was found to be well circumscribed which could be removed and dissected free from the surrounding vital structure without any difficulty. The histology of the tumor was meningioma. With the operative findings from the first stage operation suggesting the potential of totally tumor removal, therefore the patient was evaluated by balloon occlusion test for sacrifice of the left vertebral artery. After the patient passed the balloon occlusion test, the second stage, left-sided foramen magnum approach was undertaken. The meningioma was totally removed including the encased left vertebral artery. The postoperative course was uneventful and the patient recovered from his deficit and was able to walk within a few months later.

Patient 5. A 32 year-old male came to the hospital

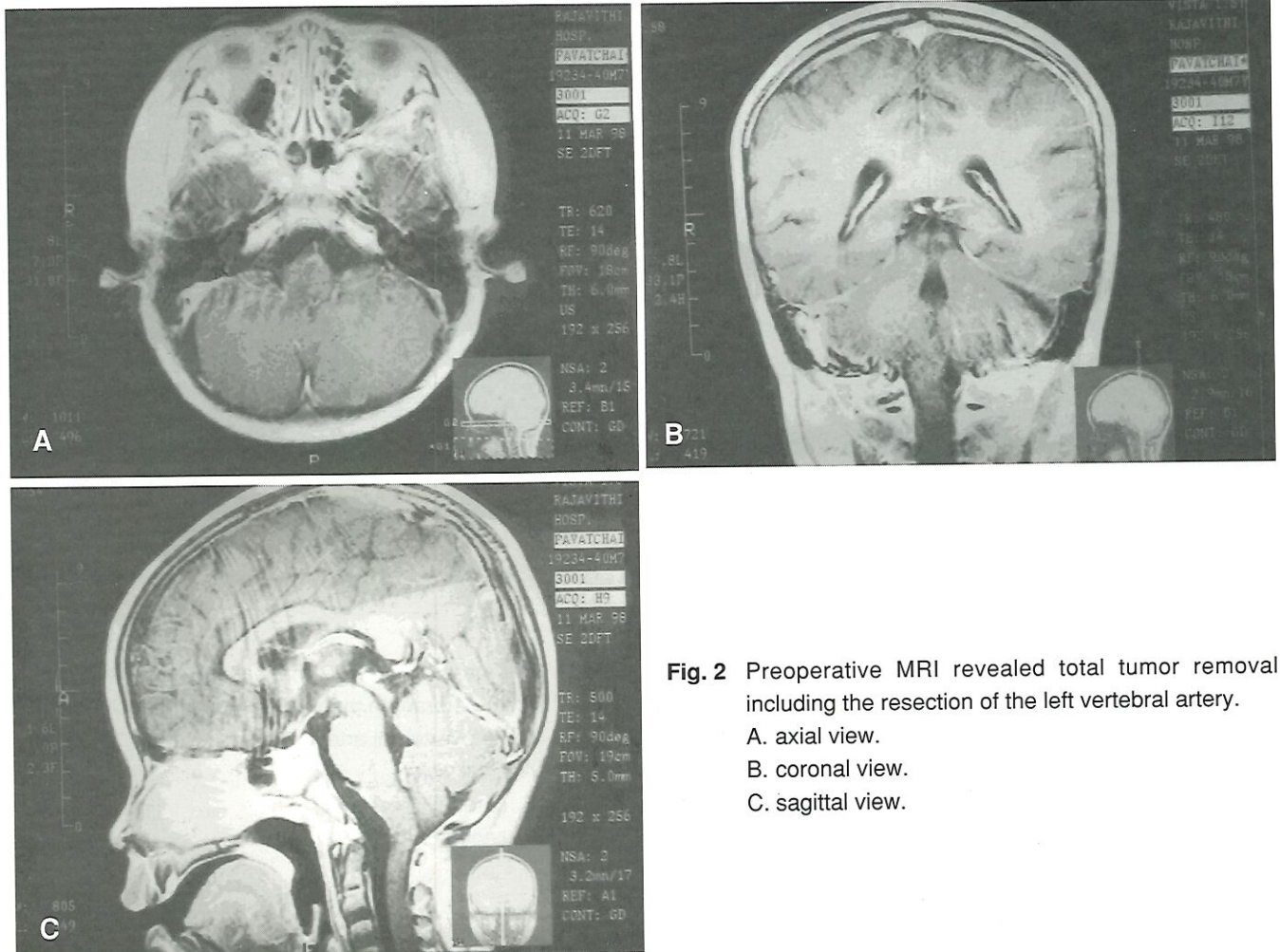


Fig. 2 Preoperative MRI revealed total tumor removal including the resection of the left vertebral artery.
 A. axial view.
 B. coronal view.
 C. sagittal view.

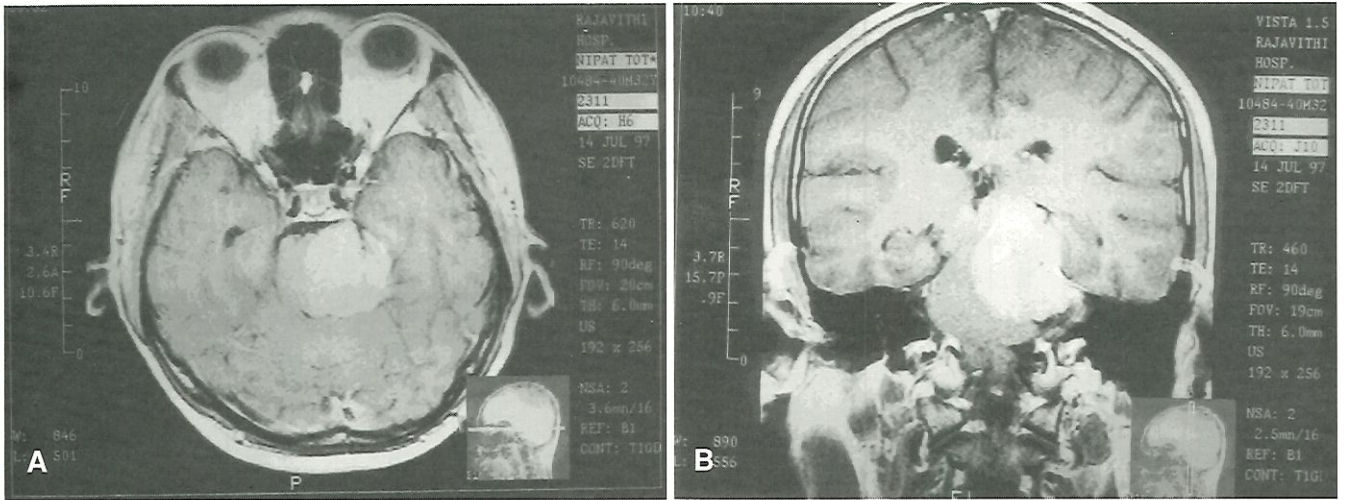


Fig. 3 MRI of the patient Case 5 showing the petroclival meningioma.
 A. axial view.
 B. coronal view.

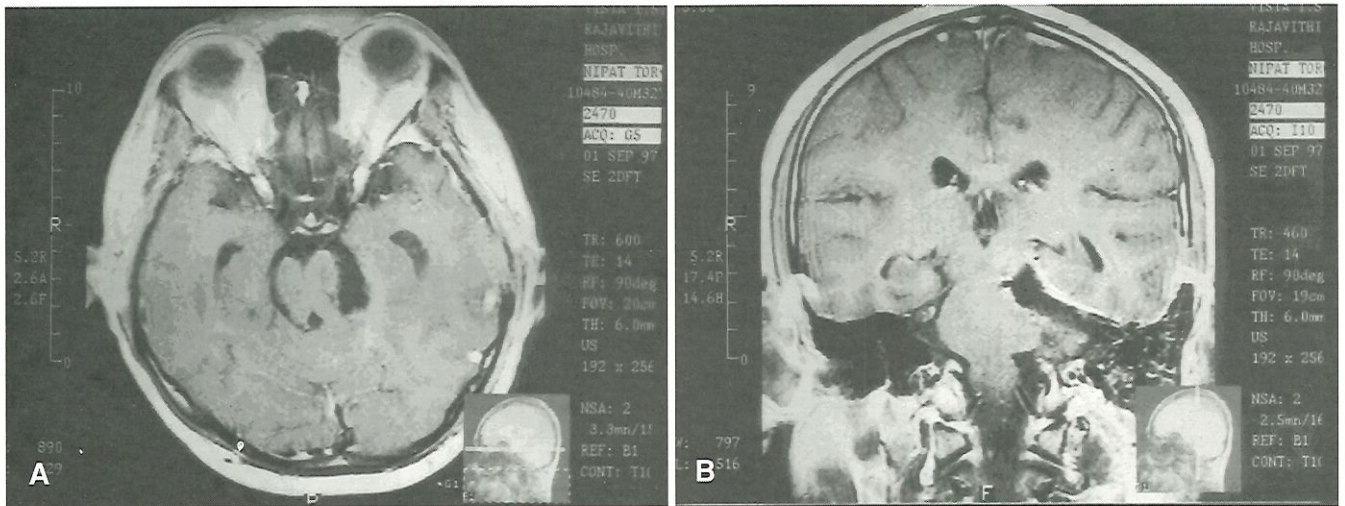


Fig. 4 Postoperative MRI revealed total tumor removal.
 A. axial view.
 B. coronal view.



Fig. 5 CT-3D scan showed the craniectomy sites of the left keyhole subtemporal and left retromastoid approach.

because of headache and right-sided weakness. The examination revealed papilledema in both eyes and right hemiparesis of grade IV/V. The CT scan and MRI revealed a tumor at the left tentorial notch extending into both middle and posterior fossae.

The two-staged keyhole approach for this patient was planned, In the first stage, the left subtemporal approach, mainly aimed at removal of tumor in the supratentorial portion. Following splitting the tentorium just behind the entry of the cranial nerve IV, some of the infratentorial tumor could also be removed.

Table 1 Summary of the cases of the petroclival and anterior foramen magnum tumor operated by 2-staged keyhole approach.

Patient	Age	Pre-op. status	Diagnosis	1st approach	Pathological diagnosis	2nd approach	Radicality	Post-op. status
1	6 yr	Quadriplegia	Foramen magnum tumor * upper ext. grade IV, * lower ext. grade IV	Rt. sided Foramen magnum approach	Meningioma	Lt. Sided Foramen magnum approach	Total removal	Complete recovery
2	35 yr	Severe headache, Lt. hemiparesis ataxia, cerebellar sign, Rt.	Rt. Petroclival tumor, hydrocephalus	Rt. Retromastoid approach	Meningioma	Rt. Subtemporal approach	Subtotal removal	Dysarthria, Lt. hemiparesis Gr. IV
3	72 yr	Coronary heart disease s/p Balloon dilatation 3 yr, Lt. hemiparesis, Rt. CN III palsy, Ataxia, cerebellar sign, Rt., confusion, disorientation	Rt. Petroclival tumor, hydrocephalus	Rt. Subtemporal approach	Melanocytic tumor	-	Partial removal residual tumor at posterior fossa	Alert, Improvement of motor weakness
4	60 yr	Headache, ataxia	Lt. Petroclival tumor, hydrocephalus	Lt. Subtemporal approach	Malignant meningioma	Lt. Retromastoid approach	Subtotal removal residual tumor at brainstem	Rt. hemiparesis
5	32 yr	Weakness Rt. Leg, Ataxia, cerebellar sign, Lt.	Lt. Petroclival tumor	Lt. Subtemporal approach	Meningioma	Lt. Retromastoid approach	Total removal	Complete recovery
6	35 yr	Severe headache Diplopia, Rt. Lateral rectus weakness, Rt. facial weakness	Rt. Petroclival tumor	Rt. Subtemporal approach	Meningioma	Rt. Retromastoid approach	Total removal	Rt. Facial weakness Impair Rt. facial sensation (V2, V3)
7	45 yr	Quadriplegia	Rt. Petroclival tumor	Rt. Subtemporal approach	Meningioma	Rt. Retromastoid approach	Total removal	Lt. Hemiplegia Ptosis Rt. eye

Pathological examination of the tumor revealed meningioma, therefore the second stage of the left retromastoid approach was performed a few weeks later. The tumor was completely removed at the second stage surgery.

The patient gradually recovered from the right-sided weakness after one month of follow-up.

RESULTS

The patients' characteristics and results of surgery are summarized in Table 1. The pathological findings revealed 4 cases of petroclival meningioma, one case each of malignant petroclival meningioma, petroclival melanocytoma and foramen magnum meningioma.

Our experience in these 5 cases of petroclival meningiomas, one melanocytoma and one foramen magnum meningioma is indeed a very small series. However, total tumor removal was accomplished in 4 out of 7 cases, i.e. 3 cases of petroclival meningiomas and one case of foramen magnum meningioma (Cases 1,5,6,7). In one case (Case 2), only subtotal tumor removal was done because of tumor adherence to the brain stem. Complete removal of tumor would involve substantial risk of brain stem damage, thus some residual tumor tissue was left behind. Another case (Case 4) with malignant meningioma, removal of tumor in the second stage was incomplete due to tumor hypervascularity and adherence to major artery. Postoperative radiotherapy was administered to these 2 cases (Cases 2,4).

There was no mortality in our experience. Two patients (Cases 1,5) recovered without any neurological deficit. Four patients (Cases 2,3,4,6) were improving from their preoperative condition. A bed-ridden patient (Case 7) with large petroclival meningioma and preoperative quadriplegia, improved only slightly even the tumor was totally removed. There was one patient (Case 3) with melanocytoma whose neurological deficit improved after first stage surgery, refused the second stage operation because of his unstable cardiac problem. Postoperative morbidity occurred in Cases 2 and 7 from brain stem ischemia resulting in postoperative hemiparesis but was transient only in Case 2. Facial numbness in Case 6 resulted from extirpation of the tumor in the Meckel's cave. Ptosis in Case 7 resulted from cranial nerve III injury during tumor removal in the tentorial area.

DISCUSSION

Skull base approaches

Between the years 1992-1993, the author had the opportunity to work as a guest surgeon in University of Mainz with Professor Axel Perneczky. The keyhole concept and keyhole surgery as a minimally invasive preferential management was studied at that time.¹

In conventional skull base technique usually a large skin flap and lot of bone work are needed before the surgeon could reach the target lesion. Extensive experience and good knowledge of the skull base anatomy are imperative for the bone work. Some approaches require translocation, osteotomy of the surrounding structures resulting in time consuming complex bony reconstruction. Postoperative CSF leakage as well as infection is common. The risk of having higher mortality and morbidity are well recognized.²

The advantages of the skull base approach are better exposure for deeply located skull base lesions and the minimal brain contusion from brain retraction. These techniques are usually employed in the large medical center because the preferred multidisciplinary team approach of neurosurgeon, ENT surgeon, and plastic surgeon.

Skull base tumors

The overall result of treatment for skull base tumors was determined by their histology, type of radical surgery, preoperative status and intra-operative complications. Tumor with benign histology has a better prognosis than malignant. Actually, the benign histology is challenging for the radical surgery because of the chance of cure and low incidence of recurrence. However, even with extensive radical procedure of the skull base surgery, some tumors do recur. The more radical surgery also associates with high mortality and morbidity.³⁻⁶ The degree of radical surgery was also determined by the tumor consistency and its adherence to neurovascular structures which could exactly be determined at time of surgery. If the operative findings is unfavorable, total tumor removal becomes not possible even by the conventional skull base technique. Recently the results of radio-surgery and radiotherapy are quite favorable.⁷⁻¹⁰ Therefore, some authors now had advocated less amplitude of surgery to maintain patients' maximal function as well as to

avoid the risk of mortality and morbidity. Then, the role of post-operative adjuvant therapy should be considered.¹¹

Minimally invasive neurosurgery and keyhole approach

Currently, minimally invasive technique plays significant role from investigation to therapeutic approaches in neurosurgery. Understanding the keyhole concept,¹ microsurgery could possibly be performed in lesions of limited or difficult exposure. To serve the minimally invasive definition, the keyhole approach must maintain its maximum efficacy without additional risk.¹² Keyhole approach could be applied to most of daily microsurgical practice in individual case following careful assessment. Modern imaging technologies such as MRI, MRA, and 3D-CT scan offer new armamentarium for planning in individual case with accuracy for the keyhole approach. Image-guided surgery and endoscopy promote the approach by keyhole surgery for maximum efficacy throughout the operative period.

Subtemporal keyhole approach

Taniguchi and Perneczky² reported favorable results of the keyhole subtemporal approach for suprasellar and petroclival lesions. This approach provides 2 corridors above and below the cranial nerve V. To approach petroclival lesion below cranial nerve V, extradural approach for petrous apex resection was required. The degree of resection was tailored in each individual case situation.

Petroclival tumor

Petroclival tumor is conventionally resected by the various approaches of skull base technique.^{2,4,5,13-17} Combined subtemporal and retromastoid approach had been a choice for this tumor before the skull base technique era. The two-staged keyhole approach (subtemporal and retromastoid) is the modification and combination of conventional combined subtemporal and retromastoid approach and the subtemporal keyhole approach.² The petrous apex resection is not required because the infratentorial portion of tumor can be extirpated from the retromastoid approach even in the case of large tumor with extension below cranial nerve V.¹⁸

Some authors reported total removal of tumor with favorable outcome. Contrarily, subtotal removal

was common in some reports. Some authors advocated more conservative surgery for this lesion in order to minimize the postoperative neurological deficit.¹¹ In this series of limited experience of 3 patients with total tumor removal and 2 patients with partial tumor removal, the outcome of two-staged keyhole approach concurred with those reported in the literature. Excluding the patient (Case 3) with melanocytoma whose second stage operation was refused, there was no mortality in the 5 cases of petroclival tumor and 4 of these 5 cases had shown definite improvement of their preoperative neurological deficit after the operation. The other patient with quadriplegia who was bed ridden had only slight improvement. Two major complications of brain stem injury were encountered resulting in transient hemiparesis in Case 2 and no improvement of preoperative quadriplegia in Case 7. Two cases with subtotal tumor removal, (Case 2) because of tumor adherence to the brainstem, had transient hemiparesis from brain stem injury. Another case (Case 4), the malignant meningioma with high vascularity and adhered to major vessel, was not aggressively removed. Radiosurgery and radiotherapy have a significant adjunctive role for these less aggressively or partially resected patients with favorable results.⁷⁻¹⁰

Anterior foramen magnum tumor

Various approaches were reported for the anterior foramen magnum tumor.¹⁹⁻²¹ The tumors which predominately extend to one side could be removed from the single-staged approach. Anterior foramen magnum meningioma in Case 1 with symmetrical extension and encompassing the left vertebral artery was a very difficult issue for surgical decision. By staging approach, the resectability of the tumor could be assessed by the first stage approach. After the benign histology of meningioma with soft consistency was recognized, the more aggressive management including balloon occlusion test to facilitate total tumor removal with the sacrifice of left vertebral artery was achieved. The postoperative course was uneventful with full recovery within a short period.

Advantage and disadvantage

This two-staged keyhole approach poses some advantages. First, this approach is performed in limited fashion, therefore minimizing tissue trauma. Second,

this comprise two approaches in different stage, therefore, shorter operative time for each stage is appropriate for the unstable patient. Third, because of small exposure needed, simple skin incision, simple craniotomy or craniectomy, the operative time from skin incision to tumor identification is shorter. Fourth, no reconstruction is needed for surgical wound closure and the postoperative CSF leakage is not the problem. Fifth, tumor histology and the tumor consistency are known after the first stage approach which assists in decision making for the radical resection in the second stage operation. Sixth, for this rather conservative approach, any complication could be minimized.

However, the disadvantage of the two-staged operations should be discussed with the patients. Both stages could be slightly modified for simultaneous setting on individual patient basis. Some of the planned second-staged approaches could be accomplished in one stage if the tumor is feasible for total removal.

CONCLUSION

In term of minimally invasive technique, base on individual patient assessment, petroclival tumor and anterior foramen magnum tumor could be successfully performed by a two-staged keyhole approach. The goal of the treatment is to improve preoperative neurological function, minimize operative mortality and morbidity of the patient rather than the radical resection of the tumor. Radiotherapy and radiosurgery have a significant role for the treatment of residual tumor. There are a lot of advantages in using this two-stage approach, but the disadvantages to perform two operative procedures should be informed with discussion until agreed by the patients and their families.

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