

En Bloc Resection of the Temporal Bone by the Lateral Approach in Carcinoma of the Middle Ear Associated with Skull Base Infiltration with Reference to the Resection of the Petrous Apex

ABSTRACT—En bloc resection of the temporal bone was performed by the lateral approach on two patients with carcinoma of the middle ear, which was associated with destruction in the temporal bone and tumor infiltration of the cranial base. In one of the patients, the petrous apex was resected along with the temporal bone.

En bloc resection of the temporal bone with the petrous apex is believed to be difficult because the internal carotid artery (ICA), cavernous sinus, and the brainstem are adjacent to each other in the petrous apex. However, the intra- and extracranial surgical procedures by this approach allow resection of the temporal bone ranging from the anterior part including the petrous apex to the posterior part including the mastoid process, the dura of the middle and posterior cranial fossae, and the sigmoid sinus, without exposure of the tumor. Special attention should be paid to the procedural points of surgery, such as, exposure of the petrous ICA, bleeding from the petrous sinus, and dural suturing in the vicinity of the apex. With regard to surgical indication, it is important to determine whether tumor infiltration is confined to the temporal bone and the dura of the middle and posterior fossa. If tumor infiltration into the petrous ICA, the dominant side of sigmoid sinus and/or the inferior cranial nerve is observed, then indication for surgery should be determined in a more critical manner.

Carcinoma of the middle ear is a relatively uncommon disease, and the prognosis is believed to be poor. The disease is surgically and radiologically treated, but no distinct method of treatment has yet been established.¹ Initial piecemeal resections were first per-

formed as a surgical treatment by Campbell et al² and Ward et al³ in 1951. However, malignant tumors of the head and neck have conventionally been treated, as a rule, by en bloc resection in which safety margins are set from the tumors. It is highly probable that piece-by-

piece resection of tumors will induce residual tumors and/or dispersion of the tumor to the surgical wound and cause local recurrence several months postoperatively. Parsons and Lewis⁴ and Conley and Novac⁵ performed en bloc resections of the temporal bones, but en bloc resection did not become popular because of the high frequency of postoperative complications. Since then, there have been many surgical reports.⁶⁻⁸ Surgery of the temporal bone is procedurally difficult because the internal carotid artery (ICA) and the sigmoid sinus are anatomically located at the temporal bone.⁷ Under these circumstances, no satisfactory results with surgical treatment have been obtained.⁸ In recent years, safe surgery of the cranial base has become increasingly possible owing to the advancement of diagnostic imaging and the introduction of reconstructive surgery using free flaps. At the temporal bone, however, the ICA, cavernous sinus, and the brainstem are adjacent to each other in the vicinity of the petrous apex. It is difficult for surgeons to perform en bloc resection of the temporal bone with the petrous apex. We performed en bloc resection of the temporal bone by the lateral approach on two patients with carcinoma of the middle ear associated with infiltration of the cranial base. The petrous apex was also resected with the temporal bone in one of the patients and favorable results were obtained.

CASE REPORTS

Case 1: A 49-Year-Old Man

Diagnosis

Diagnosis was carcinoma of the middle ear (adenoid cystic carcinoma).

Present Illness

Facial palsy was seen during treatment for left chronic otitis media. A tumor of the temporal bone was indicated and the patient was referred to our department with suspicion of carcinoma of the middle ear.

As a finding on admission, the tumor was observed to have filled the external acoustic meatus (EAM). Biopsy of the tumor tissue showed squamous cell carcinoma. On initial examination, palsy of the VIIth and VIIIth cranial nerves was present.

The preoperative CT is shown in Fig. 1. A preoperative angiogram revealed that the left sigmoid sinus was obstructed by tumor infiltration. The Labbé's vein was not dominant. The results of a balloon occlusion test and SPECT showed that temporal occlusion of the ICA was possible.

Because the lesion was histologically diagnosed preoperatively as squamous epithelial carcinoma, a rad-

ical operation was performed after radiotherapy at 45 Gy and chemotherapy (CDDP 100-mg + 5 FU 1500-mg).

Surgery

Extracranial Procedure

A C-shaped retroauricular incision was made, which is a coronary incision prolonged from the opisthotic part to the submandibular part.

The EAM was traversed, sutured with closure, and covered with a periosteal flap. The facial skin, including the auricle, was anteriorly reversed with the parotid gland and the masseter muscle after the facial nerves had been transected at the site where they emerged from the stylomastoid foramen. The temporal muscle was risen from the temporal fossa to expose the temporal bone. The zygomatic arch was taken off and the ramus ascendens of the mandibular bone was resected, including the condylar process, coronoid process, and the pterygoid muscle at the angle of the mandible. On this occasion, attention was paid to ensure preservation of the maxillary artery supplying the temporal muscle. The ICA, internal jugular vein (IJV), hypoglossal nerve, vagus nerve, and the accessory nerve were all confirmed following the submandibular and upper neck dissection, after which the ICA and IJV were exposed to the level of the carotid canal and the jugular foramen. The middle cranial fossa was opened by ligation and resection of the middle meningeal artery and the IIIrd branch of the trigeminal nerve (Fig. 2).

Intracranial Procedure

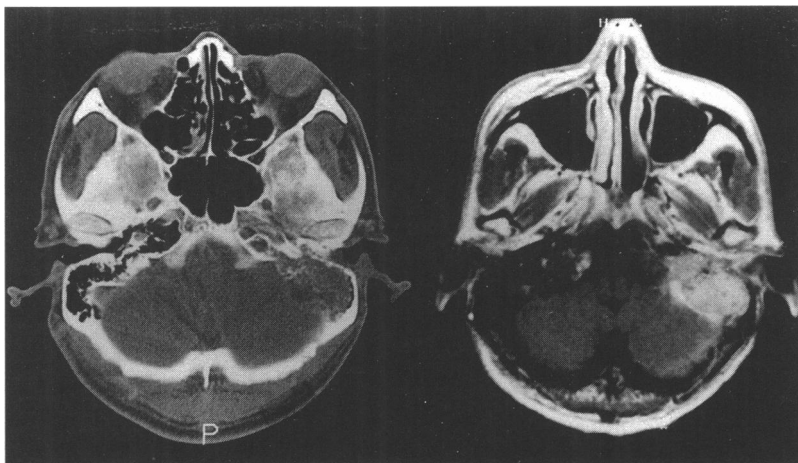
Resection line of temporal bone (see Fig. 3)

Anterior resection: After temporal craniotomy, the middle cranial base was rongeuired up to the foramen ovale. This range was set as the limiting line of the anterior resection. On this occasion, the cerebrospinal fluid (CSF) was removed through a spinal catheter in order to facilitate osteotomy.

Posterior resection: The sternocleidomastoid muscle was resected from the mastoid process, and the sigmoid and the transverse sinuses were exposed by suboccipital craniotomy. The area ranging from the median side of the mastoid process to the jugular foramen was set as the limiting line of the posterior resection (Figs. 4, 5).

Lateral resection: The tumor was radiologically observed to have infiltrated up to the inferoposterior part of the petrous ICA. The petrous ICA was opened by drilling the temporomandibular fossa in the lateral part away from the tumor. The auditory tube exposed during the process was transected and the rhinopharyngeal side of the auditory tube was packed with a piece of fat. The petrous ICA was opened in front of the cavernous sinus

Figure 1. Case 1: Preoperative computed tomography (CT) and magnetic resonance imaging (MRI). The tumor located in the temporal bone, was associated with destruction of bone tissue in a wide area, including the vicinity of the petrous apex, and had infiltrated into the cranium. On MRI, the tumor was seen to infiltrate posteriorly into the petrous ICA.



(Fig. 6). The medial side of the petrous ICA was set as a limiting line of the lateral resection because there was no tumor infiltration of the medial side of the petrous ICA.

Dural incision

Over the temporal lobe and the cerebellum, the dura was incised with safety margins set from the tumor. Because the sigmoid sinus was obstructed by tumor in-

filtration and an adequate cross-flow was revealed to have been present by preoperative angiography, the sigmoid sinus was ligated and resected at the transition from the transverse sinus to the sigmoid sinus. As a result, incisions to the supra- and subtentorial dura were prolonged superiorly and inferiorly, respectively. The tentorium was incised to the tentorial incisura in the direction of the anterior apex along the superior petrosal sinus.

En block resection of temporal bone

Medial resection of the temporal bone (i.e., from the clivus) was performed on the line connecting the jugular foramen with the petrous apex to include the sigmoid sinus and the jugular bulb. This was performed after extracranial drilling of the floor of the temporal bone using a bur. Because the temporal bone remains, this induces a poor visual field, and approach from the intracranium is difficult. Bleeding from the jugular foramen during resection of the jugular vein was controlled by packing the inferior petrosal sinus with Oxycel (Parke-Dale, Detroit, MI). When the temporal bone became mobile, the VIIth and VIIIth cranial nerves running from the pons to the internal acoustic meatus were resected in the cranium, and the acoustic artery, i.e., a branch of the anterior inferior cerebellar artery, was ligated. Ultimately, the petrous apex was resected from the clivus (Figs. 7, 8). En block resection of the temporal bone, which had been resected up to the petrous apex anteriorly and up to the mastoid process posteriorly, along with the dura of the middle and posterior cranial fossae and the sigmoid sinus, was achieved by the above procedure without tumor exposure (Fig. 9).

Reconstruction

The dural defect was reconstructed with the pericranium and the defect of the temporal bone was cov-

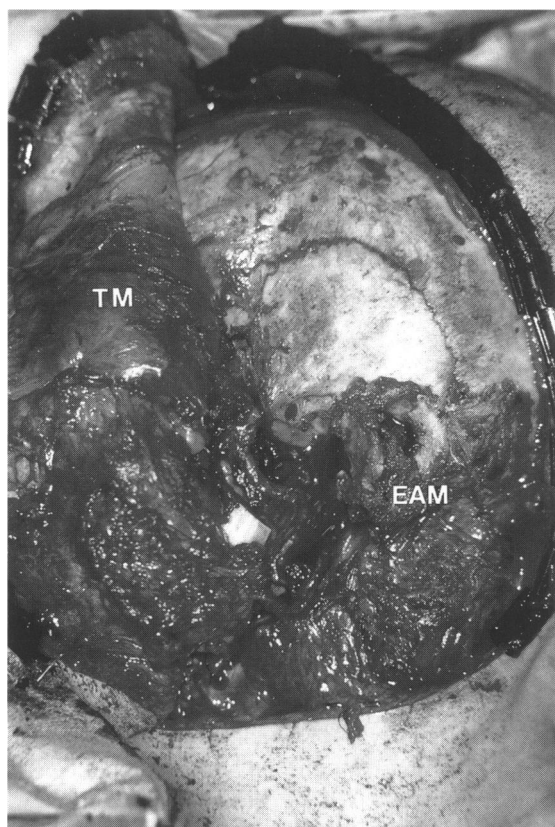


Figure 2. Exposure of temporal and infratemporal fossa. TM, temporal muscle; EAM, external auditory meatus; PG, parotid gland.

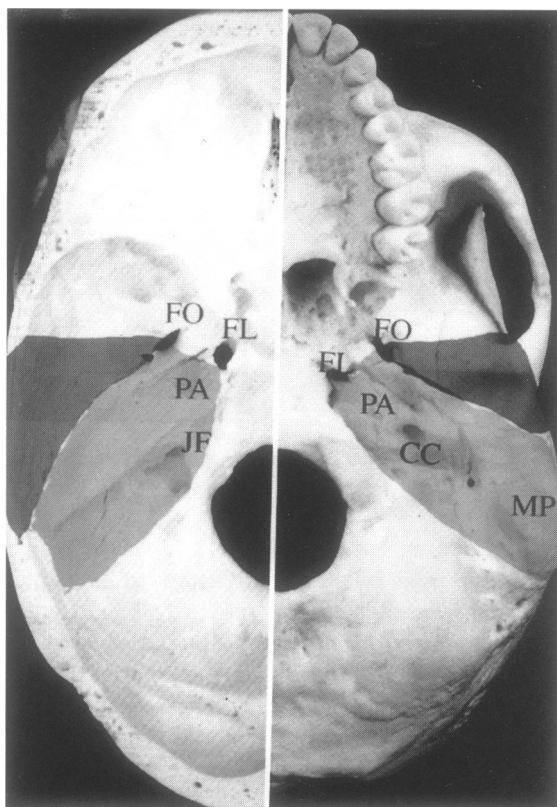


Figure 3. Left: inner view of cranial base; Right: outer view of cranial base. FO, foramen ovale; FL, foramen lacerum; PA, petrous apex; JF, jugular foramen; CC, carotid canal; MP, mastoid process. Dark shaded area, craniotomy; light shaded area, temporal bone resection. In this case, the foramen ovale, petrous apex, jugular foramen, and the carotid canal provided important landmarks. Osteotomy was performed along the resection lines connecting the following sites: in the anterior part ranging from the foramen ovale to the petrous apex, in the posterior part ranging from the medial side of the mastoid process to the jugular foramen, in the lateral part ranging from the lateral side of the carotid canal to the medial surface of the petrous ICA, and in the medial part ranging from the petrous apex to the jugular foramen.

ered with a rectus abdominis free flap. The temporal muscle was then restored, marking the end of surgery (Fig. 10).

Postoperative Course

A spinal drainage catheter was preoperatively retained for the prophylaxis of postoperative CSF leakage. During postoperative care, special care had to be taken to avoid meningitis. The tumor was pathologically diagnosed as an adenoid cystic carcinoma. The patient had no severe postoperative complications; oral ingestion became possible 1 month later and the patient was discharged from the hospital 2 months after surgery. At present, 1 year postoperatively, the patient is

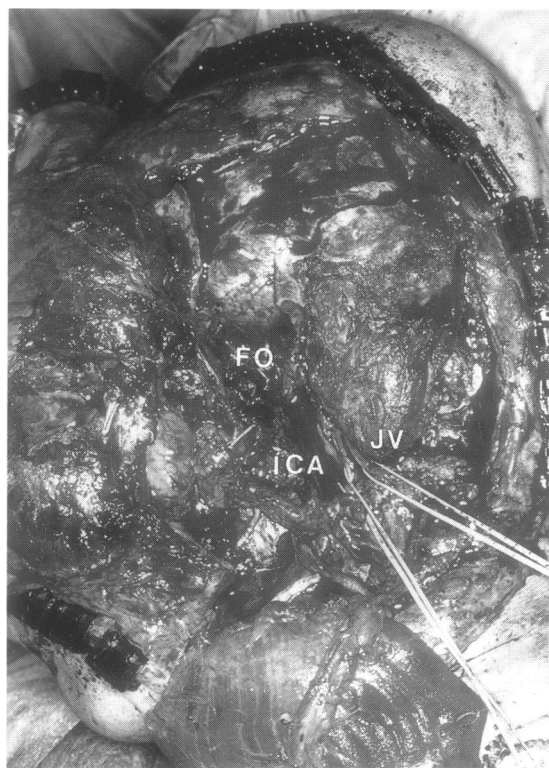


Figure 4. Temporal craniotomy was performed. CA, carotid artery; JV, jugular vein; RA, rectus abdominis flap; FO, foramen ovale.

leading life as he did preoperatively, without any difficulty in swallowing or in speech (Figs. 11, 12).

Case 2: A 70-Year-Old Woman

Diagnosis: Carcinoma of the middle ear (squamous cell carcinoma).

Present Illness

Right hemorrhagic otorrhea was observed with granulation filling the EAM. The tissue was histologically diagnosed as squamous cell carcinoma on biopsy. The preoperative CT is shown in Figure 13. The patient had no neurological symptom such as deafness or facial palsy. Preoperative radiation was performed at 40 Gy. A radical operation was performed by the lateral approach according to a surgical procedure similar to that used for case 1. The tumor was resected en bloc with the temporal bone, dura of the middle and posterior cranial fossae, and the sigmoid sinus (Figs. 14, 15). In this patient, the temporal bone was amenable to resection on posterior side of the petrous apex. Reconstruction was also performed according to a procedure similar to that in case 1; the dura was reconstructed with the pericranium, and

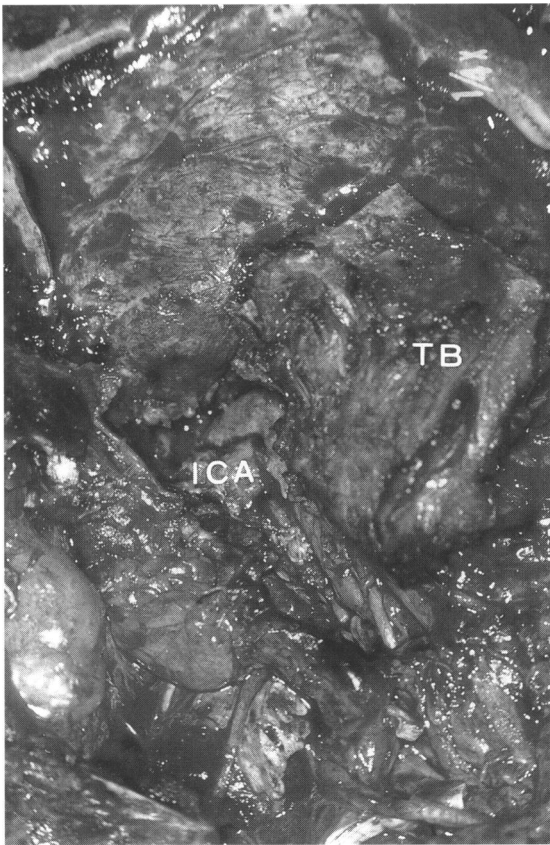


Figure 5. In addition to temporal craniotomy,[[MR 7]] suboccipital craniotomy was performed and the petrous internal carotid artery (ICA) was opened, followed by resection of the temporal bone. PA, petrous ICA; TB, temporal bone.

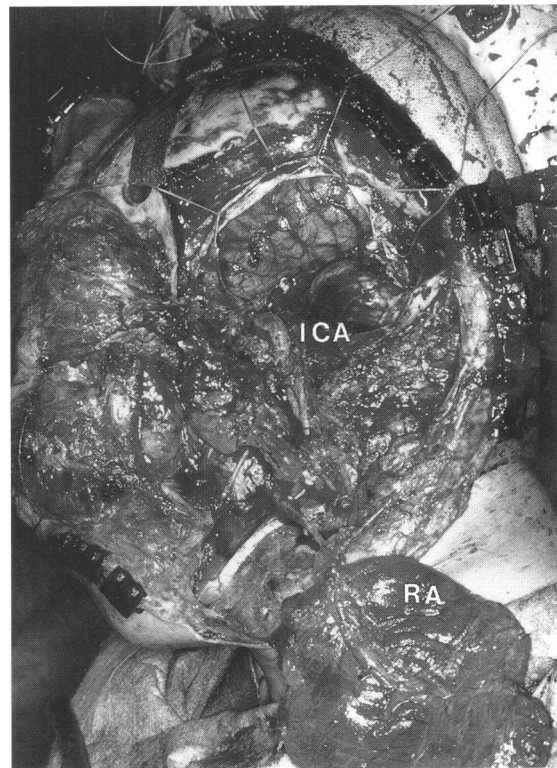


Figure 7. The petrous apex was resected from the clivus.

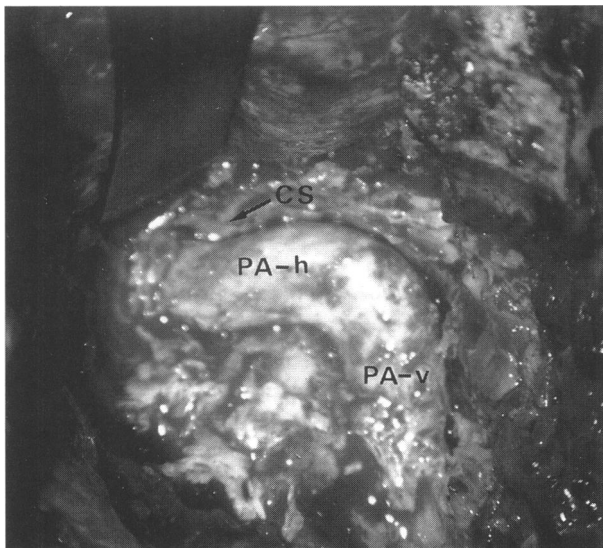


Figure 6. The petrous internal carotid artery (ICA) was opened from the carotid canal to the cavernous sinus. PA-v, petrous ICA of vertical portion; PA-h, petrous ICA of horizontal portion; CS, cavernous sinus.

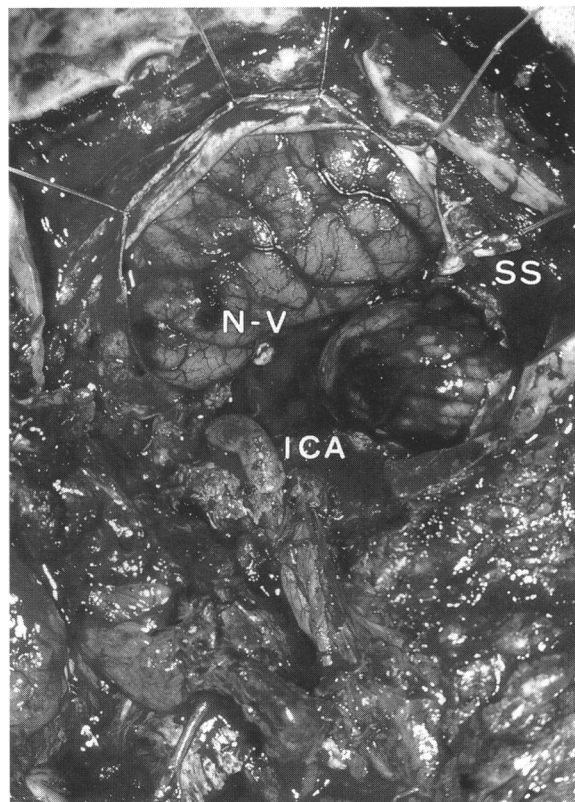


Figure 8. Enlargement of Figure 7. PA, petrous internal carotid artery; N-V, trigeminal nerve root; SS, sigmoid sinus.

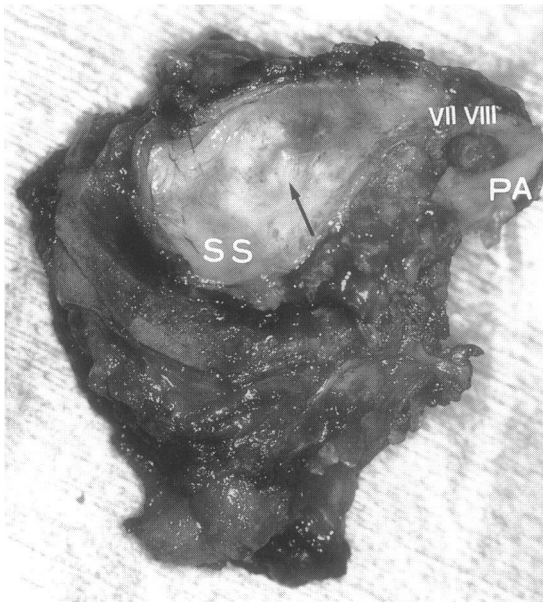


Figure 9. Case 1: specimen of en bloc resection of the temporal bone. SS, sigmoid sinus; PA, petrous apex. Arrow: dural infiltration of tumor.

the temporal bone defect was covered with a rectus abdominis free flap and the temporal muscle. The postoperative course was favorable, and 3 months after surgery the patient was discharged from the hospital. At present, 3 years after surgery, the patient is leading life as she was preoperatively (Figs. 16, 17).

DISCUSSION

The temporal bone constructs the middle cranial base (which is anatomically complex with the sphenoid bone and firmly adheres to) the clivus. Furthermore, the ICA, the cavernous sinus, and the brainstem are adjacent to each other in the vicinity of the petrous apex. Resection of the temporal bone from the clivus along with the petrous apex, in which the temporal bone remains, is accompanied by technical difficulties because of the narrow working space. On that account, resection—including the petrous apex—poses the following factors for consideration.

1. Problems in surgical procedure:
 - a. Exposure of the petrous ICA
 - b. Bleeding from the petrous sinus
 - c. Dural suture in the vicinity of the apex

For en bloc resection of the temporal bone, it is important that tumor infiltration is confined to the temporal bone and the dura of the middle and posterior cranial fossae. If this is the case, the following factors become relevant for surgical indication.

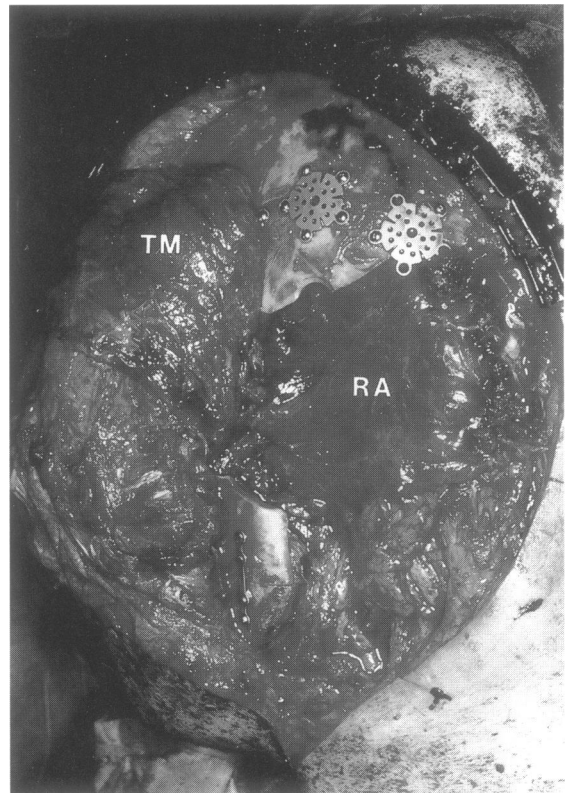


Figure 10. Reconstruction of the temporal bone was covered with the rectus abdominis free flap. RA, rectus abdominis free flap. TM, temporal muscle.

2. Problems in surgical indication:
 - a. The tumor has infiltrated to the petrous ICA
 - b. The tumor has infiltrated to the dominant side of the sigmoid sinus
 - c. The tumor has infiltrated the inferior cranial nerves

Problems in Surgical Procedure

Exposure of Petrous ICA

For reasons of safety and to set safety margins from the tumor in the temporal bone for opening the petrous ICA, the temporal bone is drilled from the temporomandibular fossa in the lateral part. The auditory tube becomes a landmark when the vertical portion in the temporal bone is exposed. In case of carcinoma of the middle ear, however, it is also necessary to confirm the presence or absence of infiltration in rapid frozen sections because a tumor may be pathologically observed in the auditory tube. In resecting the temporal bone with the petrous apex, the vertical and horizontal portions of the petrous ICA must be opened widely enough in front of the cavernous sinus. In such cases, careful examination is required under a microscope to

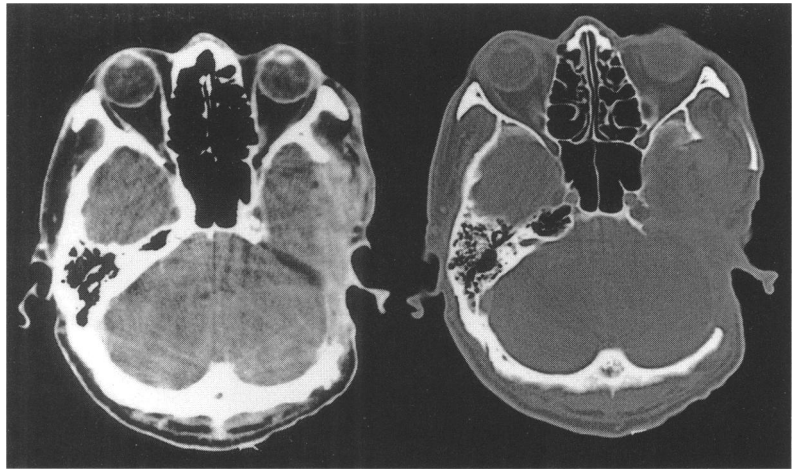


Figure 11. Case 1: postoperative computed tomography. Petrous apex was resected.

observe the small branches, such as the pterygoid artery of the petrous ICA, because bleeding from them may be induced by drilling.

Bleeding from the Petrous Sinus

The superior and inferior petrous sinuses flow into the cavernous sinus and the basilar plexus, respectively, at the petrous apex. It is difficult to ligate these sinuses

right in front of the entrance to the cavernous sinus and basilar plexus, respectively, because the operative field is narrow before the temporal bone is resected. Therefore, when resecting the petrous apex with the dura, bleeding from the petrous sinus may occur but it can be stopped by packing with Oxycel and compression.

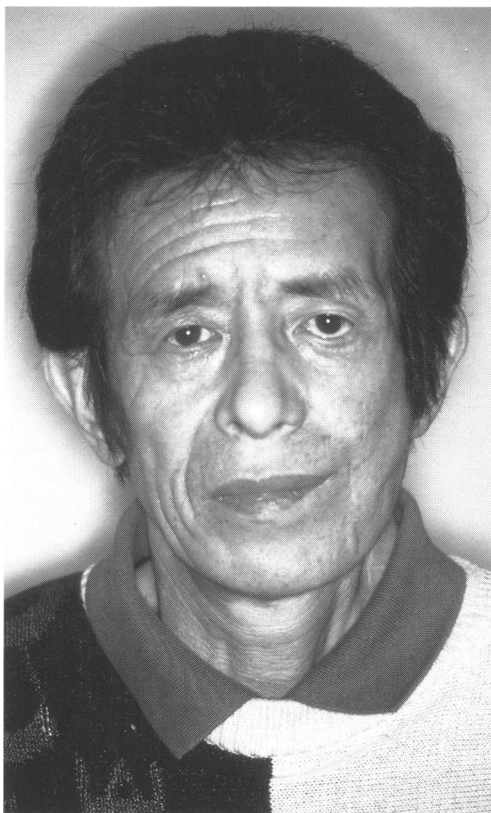


Figure 12. Postoperative face of case 1. Esthetic deformities were minimized and no skin incision was made to the facial surface.



Figure 13. Case 2: preoperative computed tomography. The tumor was revealed to have infiltrated the tympanic cavity, the antrum mastoideum, and the dura of the middle and posterior cranial fossa.

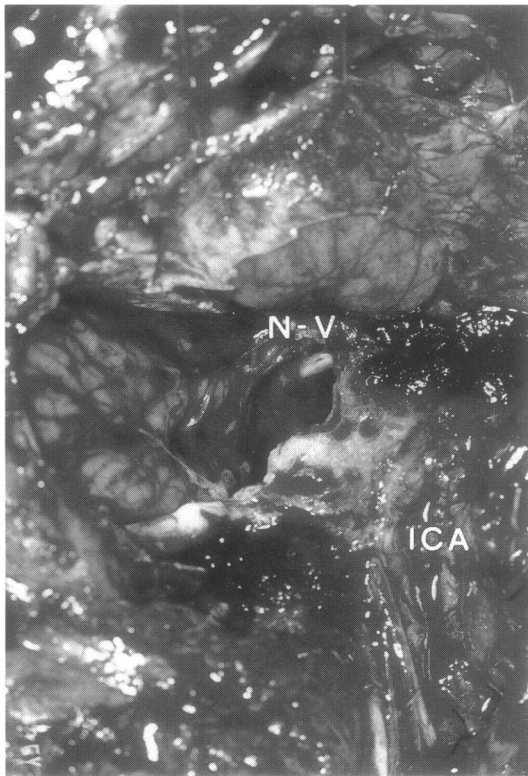


Figure 14. The tumor was resected en bloc with the temporal bone, dura of the middle and posterior cranial fossa, and the sigmoid sinus. PA, petrous internal carotid artery; N-V, trigeminal nerve root.



Figure 16. Case 2: postoperative computed tomography.

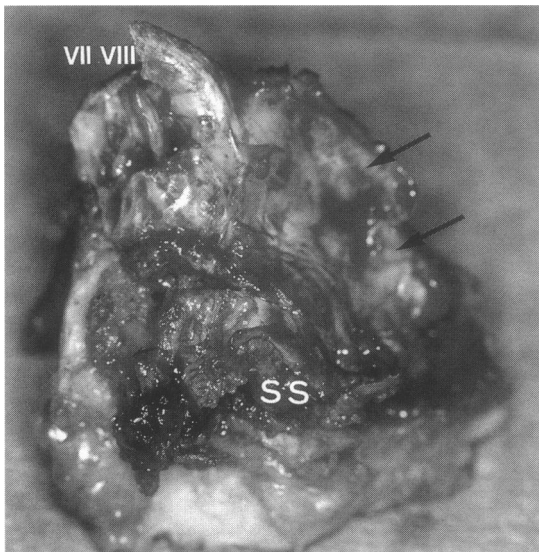


Figure 15. Case 2: specimen of en bloc resection of the temporal bone. SS, sigmoid sinus. Arrow, dura of middle and posterior cranial base.

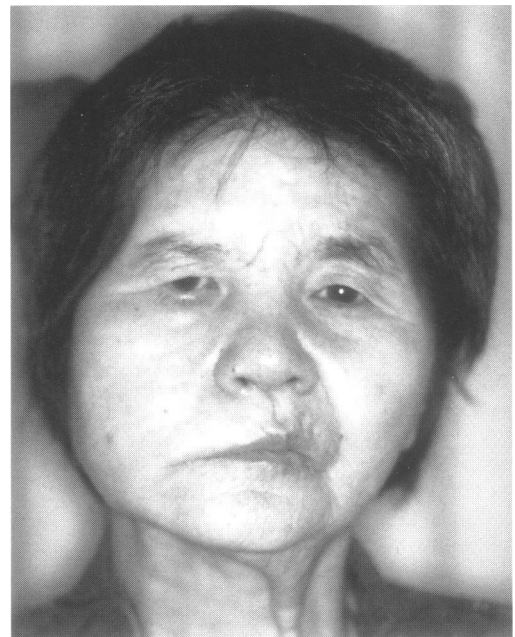


Figure 17. Postoperative face of case 2.

Dural Suture at the Petrous Apex

Because the ICA, cavernous sinus, and the brainstem are adjacent to each other in the vicinity of the petrous apex, a watertight suture of the dura is difficult. For this reason, the dura must be sealed with fibrin glue after suturing, and a spinal drainage catheter has to be preoperatively retained for drainage in order to prevent CSF leakage.

Problems in Surgical Indication

Tumor-Infiltrated Petrous ICA

With regard to resection of the temporal bone, including the ICA, Graham et al⁹ performed en bloc resection after ligation of the ICA. Sekhar et al¹⁰ and Sen and Sekhar¹¹ reconstructed the ICA and resected the temporal bone. Thus, resection of the temporal bone with the ICA is thought to be technically possible. The ICA can be resected if the cerebral blood flow volume is 30 ml/100 mg/min or more on the preoperative test.^{12,13} However, because this value is not necessarily absolute, the ICA should be reconstructed as much as possible.¹⁴⁻¹⁶ To set safety margins from the tumor, the resection must include the cavernous sinus. Vascular reconstruction must be performed over the area, ranging from the extracranial ICA to the intracranial supraclinoid ICA, to achieve en bloc resection of the temporal bone without exposure of the petrous ICA.¹⁷

Therefore, when considering intraoperative risk and postoperative neurological deficit in cases associated with tumor infiltrations of the petrous ICA, it is important to determine the indication for surgery through a consideration of the possibility of a radical cure, histological type, patient age, general condition, and so on.

Tumor-Infiltrated Dominant Side of Sigmoid Sinus

It is highly probable that marked cerebral edema may be postoperatively caused by venous reflux disturbances on resection of the dominant side of sigmoid sinus. Neurological complications may also occur due to cerebral edema. For these reasons, it is difficult to regard tumor infiltration of the dominant side of sigmoid sinus as a surgical indication.¹⁸

It is important to preoperatively measure cerebral hemodynamics and cerebral blood flow volume by cerebral angiography, balloon occlusion test, and SPECT in order to evaluate the previously described surgical indication and risk.

Tumor-Infiltrated Inferior Cranial Nerves

In patients with paralysis of the IXth to XIIth cranial nerves—particularly paralysis of the XIIth cranial

nerve—the tumor may spread widely. Because it is also highly probable that dysphagia will occur postoperatively, it is necessary for the surgical indication to be carefully determined. With regard to the VIIIth and VIIth cranial nerves, perineural invasion was observed histopathologically in cases 1 and 2, suggesting that adequate resection is necessary for carcinoma of the middle ear.

Carcinoma of the middle ear is an uncommon disease and modification of chronic otitis media, which occurs as a complication of the carcinoma at a high incidence, makes early detection difficult.^{19,20} As a consequence, many cases of the disease are frequently progressing at the time of the definite diagnosis. Despite the fact that the main treatment is surgery, the procedure is technically difficult because important blood vessels and nerves are running adjacent to each other in the temporal bone. No adequate therapeutic results have been obtained.^{8,21} However, the main cause of death from carcinoma of the middle ear was due to local recurrence and not to lymph node metastasis or distant metastasis,^{22,23} suggesting that control of local recurrence is important for improving therapeutic results. En bloc resection advocated by Parsons and Lewis,⁴ Conley and Novac,⁵ Lewis,²⁴ Ariyan et al²⁵ is considered to be a useful method of controlling the local recurrence because of the low possibilities of residual tumor and tumor dispersion. The en bloc resection of the temporal bone by the lateral approach with safety margins, which we employed with our patients, is useful for excising tumors that have infiltrated the petrous apex and the cranial base. It was also thought to be cosmetically satisfactory because aesthetic deformities can be minimized by the procedure and no skin incision is made to the facial surface.

In reference to the therapeutic result, careful determination of the surgical indication and observation of the future course are considered important because many patients, whose indications show the need for surgical procedure, are in an advanced stage of the disease.

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