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The surgical aspects of 162 consecutive procedures for removal of acoustic neuromas, performed from 1978 through 1983, are reviewed. Nearly all of the procedures were done through a retrosigmoid suboccipital craniectomy. Most used the combined skills of a neurosurgeon and an otological surgeon. Total tumor removal was accomplished in 98% of cases. There have been two recurrences and one postoperative death. The facial nerve was preserved in 81% of procedures. Facial function returned in nearly all of these patients, but the degree of return was variable. The cochlear nerve was preserved in 55 patients, but hearing was present in only 14. The most common complication was cerebrospinal fluid otorhinorrhea (12%); about half of these patients required a secondary procedure. Other complications were meningitis (5%), aspiration (3%), and hemorrhage (2%). During the period reviewed, several changes occurred in management of this disorder. These procedures are now being done by a surgical team. The neurosurgeon performs the intracranial work and the otological surgeon accomplishes the temporal bone dissection. Most patients undergo the operation in the supine rather than the sitting position. During the operation, the facial nerve is monitored continuously by electromyography with intermittent bipolar stimulation. There appears to be continuing improvement in the management of these patients.

KEY WORDS — acoustic neuroma • brain tumor • surgical complication • facial nerve function • hearing preservation

The management of acoustic neuromas has undergone a number of changes during the past 25 years. Improvements in audiometry, electroneystagmography, multidirectional tomography, computerized tomography (CT), and brain-stem evoked response audiometry have dramatically expanded diagnostic capabilities. These changes, combined with increased physician and patient awareness, have allowed the identification of tumors early, when they can be removed more easily. Refinements in anesthetic agents and improved monitoring have decreased the operative risks. Additionally, surgical techniques and instrumentation have improved. Use of the operating microscope, microinstruments, high-speed drills, and bipolar coagulation is widespread. It is increasingly common for the neurosurgeon and the otological surgeon to work as a team in the total management of these patients. All of these factors have resulted in fewer operative deaths, infrequent recurrence of tumor, more frequent preservation of facial nerve function, and an overall reduction in complications. This supports the validity of identifying these tumors at the earliest stage possible and removing them without increasing the neurological defect.

In this paper, we review the experience in all patients who had a diagnosis of acoustic neuroma and had their primary operation at the Mayo Clinic between January 1, 1978, and December 31, 1983. This represents the combined efforts of eight members of the Department of Neurosurgery and three members of the Department of Otorhinolaryngology.

Clinical Material

The 160 patients underwent 162 procedures. Ninety-three (58%) of this group were female. Ages ranged from 14 through 84 years (median 54 years). The tumors were fairly evenly divided between sides, 84 on the left and 78 on the right. Ten patients had neurofibromatosis and two of them underwent bilateral procedures during this 6-year period, which accounts for the discrepancy between the number of procedures and the number of patients. The clinical presentation and diagnostic evaluation have been reviewed elsewhere1 and will not be presented here.

Tumor size was determined primarily by CT and includes the portion of the tumor within the internal auditory canal. These tumors are grouped for conveni-
Figure 1. Distribution of size of tumors in series. Size includes the portion of the tumor within the internal auditory canal. Range 0.5 to 6.5 cm, median 3 cm.

Figure 2. The patient is placed in a supine position with the head fixed. The skin incision is 2 to 3 cm behind the ear. The craniectomy opening is approximately 4 cm in diameter. The transverse and sigmoid sinuses should be visible before the dura is opened. (Printed by permission of the Mayo Foundation.)

Figure 3. View of the posterior surface of the temporal bone as seen from anterior to posterior. This is not in the surgical position. The bone landmarks are identified. The pennant-shaped dural incision is shown by the broken line. (Printed by permission of the Mayo Foundation.)

Operative Approach

Obviously, when a number of different surgeons are performing the operation, the techniques vary somewhat. The following description outlines the procedure that is the most common at the present time. The operative procedure has four parts.

The first part is primarily induction of anesthesia. The anesthetic agent (enflurane or halothane) is administered via an endotracheal tube. An arterial catheter is inserted for continuous monitoring of the blood pressure. A urinary catheter is placed because of the intense diuresis that occurs if mannitol or furosemide is used and because of the duration of the procedure. A malleable needle is inserted into the lumbar subarachnoid space for cerebrospinal fluid drainage. During the years 1978 through 1981, all patients were placed in the sitting or semi-recumbent position for the procedure. At present, nearly all patients are operated on in the supine position (Fig. 2). The head is turned to the side and placed in a head-holder. Electrodes are placed in the upper lip and forehead for continuous monitoring of facial nerve function. When the sitting position is used, a catheter is inserted into the right atrium and the Doppler monitor is placed over the heart.

A retrosigmoid suboccipital craniectomy is performed at the beginning of the second part of the procedure. The bone defect averages 3 to 4 cm in diameter. This extends laterally into the mastoid air cells, and the sigmoid sinus is usually visible. Superiorly, the limit is the transverse sinus. The floor of the posterior fossa is the lower limit. It is rarely necessary to extend the craniectomy to the foramen magnum. Medially, there is no absolute limit. The dura is incised and the posterior cranial fossa is entered. Spinal drainage, diuresis, and a self-retaining retractor are used to move the cerebellum out of the operating field. The lower cranial nerves (ninth, tenth, and eleventh) are isolated and protected. For larger tumors, one approach might be to resect a portion of the tumor and then develop a plane between the cerebellum and the tumor.

The next part of the procedure deals with the temporal bone. The posterior lip of the internal auditory meatus and the jugular foramen are identified. The dura over the temporal bone is excised; the internal auditory meatus, subarcuate artery, jugular foramen, and endolymphatic sac are useful landmarks (Fig. 3). A pennant-shaped segment of dura is removed, exposing the posterior wall of the internal auditory canal (Figs. 3 and 4). The bone of the internal auditory canal is then removed with a high-speed drill to expose the dura.
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within the internal auditory canal. This is opened widely, the dura is incised, and the tumor is exposed and removed from within the internal auditory canal (Fig. 5). The facial nerve is identified at the lateral end of the canal in its superoanterior position, and the eighth cranial nerve is frequently identified in its inferoanterior position. The tumor is removed completely from the temporal bone. The dissection is continued between the facial nerve and the anterior portion of the tumor as it extends into the posterior cranial fossa.

The last part of the procedure is variable. With large tumors the dissection generally begins between the cerebellum and the tumor and continues around the lateral end of the tumor to separate it from the brain stem. This dissection continues anteriorly to connect with the previous dissection. After removal of the tumor, the cranial nerves are reexamined. The facial nerve is monitored continuously and stimulated with a bipolar electrode as necessary; stimulation should be at the brain stem in order to verify the integrity of the nerve. All bleeding is controlled with bipolar coagulation. Air cells are identified and bone wax is inserted as indicated. A small piece of muscle is usually placed in the internal auditory canal to decrease the likelihood of leakage of cerebrospinal fluid into mastoid air cells. A watertight dural closure is performed using either a dural graft substitute or pericranium. Before the patient leaves the operating room, movement of the face and all extremities is confirmed.

The patient is monitored in the neurosurgical intensive care unit for 24 to 72 hours postoperatively. During the first several postoperative days, fluid intake is restricted and dexamethasone sodium phosphate is administered. Patients are monitored carefully for lower cranial nerve problems such as aspiration or airway obstruction.

Operative Results

Intraoperative Problems

There were no intraoperative deaths. Only one procedure was terminated prematurely because of intraparoperative problems. This patient had hemorrhage in the region of the tentorial notch which led to incomplete removal of the tumor; the residual tumor was successfully removed 1 year later. It is estimated that there were small air emboli in approximately one-third of patients who underwent operation in the sitting position. There were no circulatory or respiratory problems, and no procedure was discontinued because of air embolus.

The facial nerve was maintained intact during operation in 131 procedures (81%). When the tumor was 2 cm in size or smaller, all nerves remained intact. The facial nerve was preserved in 86% of patients with medium-sized tumors and in only 37% of those with large tumors. Fifty-five of 162 cochlear nerves were preserved. This was possible only in patients with small tumors; unfortunately, cochlear function was seldom saved. The vestibular nerve was saved in seven cases. The tumor was in contact with the trigeminal nerve in 94 (58%) of 162 cases. There was partial destruction of the trigeminal nerve in three cases and these patients had significant postoperative facial hypesthesia. The brain stem was in contact with the tumor in 112 (69%) of the procedures; brain-stem function was maintained in all of these patients. Tumor removal was thought to be complete in all but three cases (98%). Removal was incomplete because of problems with hemorrhage or a small fragment of tumor remaining on the facial nerve. In the patient with hemorrhage, tumor did recur and has subsequently been successfully removed. The other two patients are being followed and show no evidence of recurrence at this time. Operating time ranged from 135 to 675 minutes (median 315 minutes).
Fig. 6. Distribution of degree of facial nerve function at 3 months, 1 year, and 2 years postoperatively. Note that the numbers of patients in the groups differ.

Postoperative Course

There was one death during hospitalization. This patient had a number of respiratory, neurological, and metabolic abnormalities, and died of respiratory causes approximately 6 weeks postoperatively. The most common postoperative problem was cerebrospinal fluid otorhinorrhea, which occurred in 20 patients (12%); four of these required no treatment, seven underwent lumbar puncture to reduce pressure, and nine required secondary procedures. Most of these persistent fistulas were managed with a translabyrinthine obliteration procedure as described. Three patients had postoperative hemorrhage that required further surgical treatment; all did well. There were a number of other less frequent complications (Table 1). All were dealt with in an appropriate manner.

Function of the face immediately postoperatively was unchanged or normal in 24 cases. There was delayed or partial facial weakness in 75 patients. Sixty-three patients had total facial paralysis postoperatively; in 31 it was due to transection of the facial nerve. Thirty-five patients had some type of facial nerve grafting (generally prior to dismissal from the hospital): facial nerve-to-accessory nerve anastomosis in 20, facial nerve-to-hypoglossal nerve anastomosis in 10, end-to-end repairs in the posterior cranial fossa in four, and a cable graft in the posterior cranial fossa in one. The eye was frequently protected with a plastic bubble while the patient was recovering facial function. Thirty-nine patients had a lateral tarsorrhaphy and six patients had a gold weight inserted in the upper lid. Both procedures are easily reversible.

Hearing can be preserved when this approach is used. Fourteen ears (11% of those with preoperative hearing) have residual hearing, and all were in patients with smaller tumors. No patient had normal hearing postoperatively. Eight had serviceable hearing and six had poor hearing. Postoperative hearing was better in two, unchanged in five, and worse in seven of these patients. This is reviewed in more detail elsewhere. The period of hospitalization ranged from 7 to 64 days (median 14 days).

Follow-Up Results

The typical follow-up program for these patients requires office visits at 3 months, 1 year, 2 years, and 7 years postoperatively. Computerized tomography is done at the 2- and 7-year visits. Audiometry is done whenever hearing has been preserved. Electromyography is sometimes performed when facial nerve function is poor and consideration is being given to performing some type of anastomosis.

Follow-up data in this report include 124 procedures reviewed at 3 months postoperatively, 85 procedures at 1 year, and 66 procedures at 2 years. Balance was impaired in 50% of patients at 3 months, 36% at 1 year, and 23% at 2 years. Only two or three patients were significantly incapacitated by their balance problems beyond 1 year. Absence of facial nerve function was common at 3 months and very infrequent thereafter (Fig. 6). The percentage of very good results remained about the same over time. The results between these extremes tended to improve up to 2 years. The facial function data are subjective: presence of tone but no movement, approximately 10%; facial tone and some voluntary control, approximately 50%; and good voluntary movement and facial expression with synkinesis, mass movement, excessive tearing, or lagophthalmos, around 75%. The finding is discussed with the patient and the patient generally concurs with our impression.

To date there have been two recurrences among the 162 procedures. One was anticipated and has been discussed above. The second was in a patient who had the initial operation in 1978; the recurrence was discovered in 1983. The point of recurrence appears to have been in the internal auditory canal, and this second tumor has been successfully removed.

Discussion

This review confirms our confidence in the surgical management of these patients. Morbidity and mortality rates are low, and complication rates are acceptable.
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Tumor removal was nearly always total, facial function was generally preserved, and hearing was occasionally preserved. These procedures are generally performed by a team. The neurosurgeon operates intracranially and the otological surgeon accomplishes the temporal bone dissection. There is overlap and excellent cooperation. During the first 4 years, all patients were operated on in the sitting position, but now nearly all of these operations are done with the patient in the supine position. There was no precipitating event that led to this; however, we had concerns about potential hazards of the sitting position. The use of spinal drainage through a malleable No. 18 lumbar spinal needle enhances exposure with minimal retraction and has not caused any technical problems. Most recently, intraoperative monitoring by electromyography has been used to enhance identification and preservation of the facial nerve.

We think that the posterior cranial fossa approach as described here has advantages. The exposure is good, regardless of tumor size, and control of bleeding is easier, particularly in the region of the brain stem. It is possible to preserve facial and cochlear function. In cases in which the preoperative diagnosis is incorrect, it is possible to explore without destroying cochlear or labyrinthine function. In addition, if other surgical procedures are indicated, one can generally continue surgery rather than close and reoperate at a later time.

The major criticisms of this procedure are the difficulty of identification of the facial nerve at its distal point, and the possibility of residual tumor in the lateral end of the internal auditory canal. The facial nerve is routinely identified within the internal auditory canal. We have always been able to make this identification. In fact, the most difficult area of identification is medially, at the anterior lip of the internal auditory meatus. As the facial nerve exits from the internal auditory meatus, it becomes extremely thin and its relationship to the tumor may vary considerably. Electromyographic monitoring with bipolar stimulation has been helpful in this situation. When the facial nerve is severed, the division is always in the posterior cranial fossa. The lateral end of the internal auditory canal can be difficult to visualize; however, if there is any doubt, the dissection is extended into the otic capsule, and the vestibule and posterior semicircular canal may be opened. Obviously, hearing cannot be preserved but hearing preservation is secondary to total tumor removal.

We think that spinal drainage, occasional use of mannitol or diuretic agents, and use of the supine position have minimized the need for retraction or amputation of the lateral cerebellum. Intraoperative monitoring of facial nerve function and the combined otological and neurosurgical approach have minimized inadvertent trauma to the facial nerve by early identification of the nerve both medially and laterally. More recently, the CO2 laser and ultrasound instruments have been useful in debulking some larger tumors. Although further monitoring techniques (such as cochlear nerve monitoring) and other advances in instrumentation might be of benefit, we think that the combined medial and lateral approach to an acoustic neuroma has been the single most important technical advance in the treatment of this tumor at our institution.

References


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