Surgical Treatment of Acoustic Neuroma with Preservation or Reconstitution of the Facial Nerve*

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The treatment of the innocent acoustic neuroma has, in a sense, been the most challenging of all intracranial tumors during the recent history of neurological surgery. Although readily accessible by a posterior fossa approach, its intimate involvement with the brain stem, cerebellum, cranial nerves, and the vessels irrigating these structures has taxed the ingenuity of the finest surgeons.

History

The early surgical treatment was done primarily on very ill patients who had far advanced large tumors and consisted of an intracapsular removal of the bulk of the tumor, as described by Cushing. Subsequently, encouraged by the reports of Dandy, Olivecrona and McKenzie concentrated on and developed the modern technique for safe complete extirpation of the tumor. The extent of the problem was indicated by an over-all mortality of 25% in 300 cases in the hands of Olivecrona who pioneered efforts to save the facial nerve. McKenzie’s concentration on the difficulties posed by this tumor resulted in a mortality of 12.5% in 142 patients. In these advanced cases, much of the neurological dysfunction due to the mass of the tumor was irreversible. Hemorrhagic softening of the brain stem was the chief cause of operative mortality and morbidity, and resulted from injury to the anterior inferior cerebellar artery. This vessel usually is intimately related to the tumor which it supplies with blood; it also has a wide field of irrigation in the adjacent brain stem. The facial nerve was sacrificed more often than not in the interest of safe tumor removal, and the clinical results of facial nerve anastomosis to the hypoglossal, accessory, or phrenic nerves were barely acceptable.

Partial removal was practiced in older patients, in those with serious systemic disease, in those who would not accept facial paralysis, or in cases where the tumor was largely cystic. It was realized that incomplete removal of this tumor was not satisfactory for the majority of patients in the long run. The intracranial pressure problem was unrelieved when the extension of the tumor through the incisura was not removed, or when adhesive arachnoiditis developed probably because of an exudate from the residual tumor. Growth of the residual tumor, even when a small fragment, led to difficulty in a few years in one third to one half of the cases. Olivecrona has stated that 60% of those with partial removal were dead within 3 to 4 years, either from the immediate effects of operation or recurrence.

As techniques improved and more tumors were recognized at less advanced stages, facial paralysis assumed more importance and became the sequel that patients found most difficult to accept. Attention was directed to preservation of the nerve or restoration of its function by extrapetrous graft or direct anastomosis in the posterior fossa.

With the development of microsurgical techniques, Kurze and Doyle and House advocated an extradural middle fossa approach through the temporal bone to save the facial nerve. However, the exposure proved to be too confining with any but small tumors. House then refined the trans-labyrinthine approach in an effort to increase the access to the angle. It became clear that, with prolonged dissection through the temporal bone under the microscope, the internal auditory canal and its orifice could be enlarged to expose the origin and lateral aspect of an acoustic neuroma and the seventh nerve. Small tumors and those confined to the canal could be seen in their entirety.

Nevertheless, there has been concern about the safety of the transpetrous procedure, particularly with larger tumors. Although preservation of the facial nerve is...
important, it should in no way jeopardize the life or function of the patient or the completeness of the extirpation. The major disadvantage of this lateral approach is that the most important part of the dissection, along the brain stem, is hidden from the operator by the tumor mass. It is here that all the troubles from operation have arisen, even with the direct access of suboccipital exposure.

It is unlikely, even inconceivable, that with a large tumor the transpetrous route will result in less injury to the ninth and tenth nerves, the pals, and the medulla, or avoid the devastating infarction of the brain stem and cerebellum unless the anterior inferior cerebellar artery is seen and preserved. There is no doubt that this part of the dissection must be done under direct vision. Rand and Kurze have pointed out that, in addition to the limited field of action, total hearing loss is produced prior to the identification of a tumor unless the middle fossa approach is used. There is no opportunity to reconstruct the facial nerve if involved by tumor and there is an increased risk of a CSF leak. If partial removal is indicated, there is no need for the extensive trans-labyrinthine procedure to spare facial action. The operation would be more radical and safe through the posterior fossa.

**Analysis of Cases**

An analysis of House's cases (Table 1) reinforces these contentions. The size of an acoustic neuroma is unquestionably the most important factor as far as the safety of the surgical treatment and the clinical picture is concerned. For the purpose of comparing the House series with ours, we have created four categories:

1. Involvement of the auditory nerve only (C-VIII).
2. Involvement of the auditory and trigeminal nerves (C-VIII and C-V).
3. Involvement of C-VIII and C-V and the cerebellum.
4. Involvement of C-VIII, C-V, cerebellum, and the glossopharyngeal and vagus nerves (C-IX and C-X).

Categories 1 and 2 involve small tumors while Categories 3 and 4 are associated with large angle masses. Preoperative impairment of the facial nerve is usually slight, even with large tumors, and therefore was not included in this categorization.

It can be seen from Table 1 that House's operations were all on tiny or small tumors. This is a tribute to modern otological and radiological diagnosis. On the other hand, only 2 of the 30 neurosurgical cases were small tumors; the remainder were large, and 12 (40%) had choked discs. Three were bedridden (2 with hemiparesis), and 4 others could not walk unaided because of ataxia. Therefore, any comparisons made between the otological operations or small tumors and the standard neurosurgical procedure for the average large tumor are invalid and misleading.

It can also be seen that the factors mitigating against the transpetrous operations for large tumors (vide supra) are also important with small angle tumors. Three of 4 middle fossa operations and 12 of 13 trans-labyrinthine operations resulted in incomplete removal of tumors just large enough to compress the trigeminal nerve. The trans-labyrinthine operation resulted in incomplete removal in 4 cases where only the eighth nerve was involved. Thus, 19 of 50 small tumors (38%) were incompletely removed. It is reasonable to consider that most if not all of these smaller tumors would have been subject to complete removal by the suboccipital approach. The surgical mortality, 2 deaths in 51 cases, is notable. No clearer argument can be used in support of the need for earlier diagnosis and operation when the tumor is small. The only large tumor operated upon died after incomplete removal through a combined middle fossa and trans-labyrinthine approach. These figures tend to confirm Mayfield's observation that the otologists are operating upon "ear tumors" while neurosurgeons have been dealing with brain tumors. Even so, our attitude should still be one of admiration for a remarkable piece of work which has aided in diagnosis, led to reassessment of the transpetrous procedures, and emphasized the importance of magnification.

The remarkable report of Hullay and Tomits is an indication of the low morbidity and mortality possible with the neurosurgical operation. In their series of 50 patients the tumor was large in 14, medium in 23, and small in 13. Complete extirpation was carried out in every case, with only 2 post-
operative deaths. The facial nerve was saved in 32 patients and was functioning wholly or partly in all but 5. All the survivors (47) were able to return to their former occupation.

Dott⁶ has stated that the right time to remove an acoustic neuroma is when it is no larger than a grain of wheat. During the period of neurosurgical development, the otologists were exploring techniques to differentiate the causes of nerve deafness more accurately. Beginning with the studies of Dix and Hellpike,⁴,⁵ the gamut of investigation now includes a study of the calorice responses, patterns of pure tone loss, speech discrimination, Békésy audiometry,²⁵ and loudness balance including the short increment sensitivity index (S-1 S-1 test). In suspected cases, small tumors and even those still confined in the meatus can be outlined graphically using positive contrast studies.²¹ At this stage the spinal fluid protein may be normal. Johnson and Sheehy have summarized the techniques for the benefit of neurosurgeons.¹⁷

As a result of the refinements in diagnosis, these tumors should be recognized and operated upon when they are very small. Removal should be complete and there should be little difficulty in saving the facial nerve. Among the 31 small tumors (60%) that could be completely removed by a transpetrous operation, House was able to save the continuity of the facial nerve in all but one case (1 anastomosis). Among the middle fossa operations, there was little or no facial paralysis in 2, paralysis with subsequent satisfactory recovery in 4, and no recovery in one. Following translabyrinthine total removal, there was little or no paralysis in 13, paralysis with subsequent satisfactory recovery in 7, and no recovery in 3.

I have recently removed a small tumor which was no larger than a grape. The following is a brief summary of that case.

**Case Report**

M.K., a 40-year-old woman, had had tinnitus and progressive deafness in the right ear for 18 months. Slight intermittent subjective numbness in the temple was the only other symptom. Partial nerve deafness, absence of calorice responses, no recruitment, and a spinal fluid protein of 56 mg% were the only positive findings. A good air encephalogram including the angle cisterns and a vertebral angiogram was normal.

The right cerebellopontine angle was explored through a small lateral suboccipital craniectomy, which was enlarged when the presence of a tumor was verified. The tumor was totally removed in a few minutes; the facial nerve and its function were easily spared. The capsule was also dissected free from the acoustic portion of the eighth nerve in the porus and the main trunk preserved. The only reason that the eighth nerve was saved was because it was thought to be the seventh at first. Even so, useful hearing did not return.

**Discussion**

There is no doubt that in the future the satisfactory treatment of acoustic neuroma

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**TABLE 1**

*Comparison of 51 otological operations by House with 30 neurosurgical operations by Drake*

<table>
<thead>
<tr>
<th>Operation</th>
<th>Category 1* (C-VIII only)</th>
<th>Category 2 (C-VIII, C-V)</th>
<th>Category 3 (C-VIII, C-V, Cerebellum)</th>
<th>Category 4 (C-VIII, C-V, C-IX, C-X, Cerebellum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Middle Fossa Operations (House)</td>
<td>6</td>
<td>1</td>
<td></td>
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<tr>
<td>Complete</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Incomplete</td>
<td></td>
<td></td>
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<tr>
<td>40 Translabyrinthine Operations (House)</td>
<td>23</td>
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<tr>
<td>Complete</td>
<td></td>
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<tr>
<td>Incomplete</td>
<td></td>
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</tr>
<tr>
<td>30 Suboccipital Operations (Drake)</td>
<td>2</td>
<td>14</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Complete</td>
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<td>Incomplete</td>
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* Categories relate to clinical estimate of tumor size based on extent of cranial nerve and cerebellar involvement.
will depend upon early diagnosis by the otologist and radiologist. Once a tumor is suspected the angle should be explored, possibly by the transpetrous route or more easily through a small lateral suboccipital craniotomy. These tumors can be removed simply, sparing the facial nerve and avoiding the problems of brain stem injury. In addition, it may prove possible to spare useful hearing where tiny tumors have a clear origin from the vestibular nerves and can, with magnification, be separated from the cochlear fibers. House\textsuperscript{15} has done so in 3 of 5 cases. McKissock,\textsuperscript{11} in 1954, emphasized the importance of early diagnosis with a report on surgical treatment in 3 cases in which the tumors varied between 1.0 and 1.5 cm in diameter. He commented on the simplicity of their removal without causing facial paralysis or increasing the preoperative level of deafness.

Unfortunately, it is still the lot of the otologist and neurosurgeon to see most patients with acoustic tumors at a more advanced state of illness. Their concern will remain with the safe removal of large tumors and the preservation of the facial nerve and its function.

The difficulty in saving the facial nerve in the standard neurosurgical operation has been at the internal auditory meatus (porus) particularly when it was not eroded. The enlarged porus made preservation of the facial nerve fairly simple. After the tumor was separated from the rim or, if necessary, the posterior edge removed with a fine punch or narrow osteotome, the intrameatal portion of the tumor could be tilted out to expose the nerve in front. When the porus was small, all too often the nerve was shredded or torn during the final stages of removal of the tumor, or during coagulation of the interior to assure destruction of an intrameatal tumor fragment. It was then necessary to resort to extrapetrous grafts\textsuperscript{7,9} or direct anastomosis\textsuperscript{10} to restore some degree of natural facial function.

These difficulties due to a small porus have been overcome by a more aggressive removal of the posterior rim under magnification as suggested by Dott.\textsuperscript{8} Some years ago, in dissections of the normal internal meatus with a dental burr under direct vision, it seemed that exposure of the facial nerve within would result in an extensive operation. However, Rand and Kurze, with the aid of the dissecting microscope and more efficient and safe drills, have shown that it is a relatively simple procedure. Our subsequent experience has been that with a modern drill and, if necessary, a lesser degree of magnification with a Loupe or even direct vision, the posterior wall of the meatus can be removed easily and safely to expose the nubbin of tumor within and its origin from the acoustic nerve. This pole of the tumor can then be tilted out cleanly to expose the flattened facial nerve lying along the front wall. Further backward and medial displacement of the tumor allows the nerve to be dissected free from the capsule for 1 or 2 cm. This part of the operation should be done before the field becomes obscured from oozing, although a large tumor may have to be gutted to expose the meatus clearly. The natural slant of the opening is important even when the porus is small; this has allowed 3 tumors to be teased out of small pori without drilling.

Transmeatal microdissection is simply a refinement of the older punch and chisel method used in the enlarged porus. Its importance lies in the fact that it is efficient and can be used on normal thick-walled meati with both large and small tumors. The time spent does not place the patient in more jeopardy; there is little or no bleeding, the retraction is light, and the brain stem and cranial nerves are not being disturbed. Ojemann\textsuperscript{5,20} use of translabyrinthine dissection as a prelude to the suboccipital operation will probably prove to be unnecessary.

It has not seemed worthwhile to resect the outer third of the cerebellar hemisphere as it does not amplify the exposure along the brain stem. It was done only in the first two cases in this series. The impression that more postoperative cerebellar dysfunction occurred may not be true in view of Pool’s analysis.\textsuperscript{22}

When the dissection at the porus has been completed, the tumor is gutted and redundant portions of the capsule excised to reduce its bulk so that the most important part of the operation may begin, namely, the separation of the capsule from its blood supply as well as the lower six or seven cranial nerves and the brain stem. Ordinarily, the ninth, tenth, and eleventh nerves are carefully freed from the lower pole and protected by cottonoid as the first step after the tumor has been identified. Great care must be taken to
preserve the anterior inferior cerebellar artery. The auditory nerve is sacrificed except in the case of very small tumors. The abducent nerve is seldom adherent and can be seen when looking up underneath the capsule.

Usually it is not difficult to find and free the proximal segment of the facial nerve. It begins above and behind the origin of the sixth and runs as a flattened white band forward along the side of the pons. Further removal of capsule allows the tumor to be teased down so that the fifth nerve, particularly its soft indistinct origin from the pons, can be separated from the anterior pole. The petrosal vein usually must be conagulated and divided at this stage but may be separated and left intact. The final fragment of tumor, now mobilized, can be rotated so that the central segment of the facial nerve can be dissected meticulously from the capsule. If the nerve is inadvertently torn or involved by tumor, a primary anastomosis can be carried out in the angle.10 We have made five anastomoses of this sort; only one clinical result was unsatisfactory.

Results

Table 2 summarizes the results of our 30 cases of acoustic neuroma. All but two were large tumors associated with well-advanced clinical syndromes (Table 1). Removal was deliberately incomplete in three patients because of age, cystic nature, or the refusal to accept facial paralysis.

In the remaining 27 cases, removal was complete. It was possible to save the facial nerve in all but 5 patients (13), or reconstitute the nerve by direct anastomosis (5), or a graft (4). It is to be noted that during the last 5 years in 18 cases of total removal the facial nerve was sacrificed in only 3 cases. It was saved in 11 and reconstituted in 4 by direct anastomosis in the angle.

There were 4 deaths, all in the group where the nerve was saved in continuity, and all from postoperative hemorrhage. However, it was felt that the effort to save the facial nerve did not contribute significantly to the mortality. Each patient who died had roused from the anesthetic before showing the effects of a clot. One of these patients lived for 5 weeks following removal of an acute subdural hematoma which probably resulted from ventricular puncture. The other 3 deaths resulted from postoperative clots in the angle, in spite of prompt re-exploration. The bleeding in each case arose from a small artery in the apex of the angle which was not bleeding after the removal of the tumor in the sitting position. In this position, however, there may be a gradient of arterial pressure which is 15 to 20 mm Hg lower at the level of the brain stem than at the arm cuff. The initial bleeding may cease spontaneously under the effects of relative hypotension only to start up again when the patient becomes recumbent. This catastrophe might be prevented either by raising the blood pressure artificially before closing the dura, or by keeping the patient in a semi-sitting position in the recovery room.

It should be reiterated that if removal of the tumor begins to prove difficult and time-consuming, thus adding to the peril of the procedure, the search for the nerve should be abandoned and the tumor mobilized and removed.

Table 3 shows that when the tumor was totally removed the best postoperative facial action resulted if the nerve could be saved or reconstituted by direct anastomosis. Analysis of these results must take into account the changes that follow regeneration. Facial action will be normal when the nerve is spared easily with small or particularly soft tumors and function remains or returns quickly after operation (2 cases).

However, the nerve may be stretched to more than twice its normal length by a large tumor and the removal of this thin strand from its intimate relation to the capsule as well as its blood supply inevitably results in axonal injury and postoperative facial paralysis. Nevertheless, it can be seen that 60% had satisfactory recovery of facial action (2 cases are too recent for reliable assessment). The patient can be assured that some

<table>
<thead>
<tr>
<th>Status of Facial Nerve</th>
<th>Tumor Removal</th>
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<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Saved in continuity</td>
<td>13</td>
</tr>
<tr>
<td>Anastomosis in posterior fossa</td>
<td>5</td>
</tr>
<tr>
<td>Extrapetrous graft</td>
<td>4</td>
</tr>
<tr>
<td>Sacrificed</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
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</tbody>
</table>

Surgical Treatment of Acoustic Neuroma 463

Facet of facial nerve in 30 cases of acoustic neuroma
regeneration will take place, since the nerve is intact; but the ultimate degree of facial movement will be modified by the amount of paresis and mass movement resulting from inadequate regeneration. These changes are more evident following an extrapetrous graft or the direct anastomosis of a nerve divided in the posterior fossa. The need for the former procedure should steadily diminish, for with earlier diagnoses and smaller tumors, the facial nerve will be saved in the majority of cases.

Summary and Conclusions

Future improvement in the treatment of acoustic neuromas depends upon early diagnosis based on intensive investigation of unilateral sensorineural hearing loss. The otolaryngologist should refer the patient to the neurosurgeon when the tumor is small. The extensive translabyrinthine operation seems unnecessary regardless of the size of the tumor. The addition of a dissection at the porus usually makes it possible to save the facial nerve; otherwise it may be reconstituted by extrapetrous graft or direct anastomosis in the angle. We have noted satisfactory postoperative facial action in 60% of 23 cases in which large tumors were totally removed.

References

15. House, W. F. Personal communication.