Hearing Preservation by the Extended and Nonextended Middle Cranial Fossa Approach for Acoustic Neuroma

Abstract—The results of 248 cases of acoustic neuroma surgery carried out mainly by the extended middle cranial fossa approach during a 16-year period from 1976 to 1991 are analyzed. Hearing preservation was attempted in 69 cases and successfully achieved in 35 (51%) cases. Hearing was preserved in 24 (57%) of 42 cases in which a tumor was 20 mm or smaller in diameter, pure-tone hearing level was 50 dB or lower, and speech discrimination score was 50% or higher. The hearing preservation rate (76%) in the cases with a tumor extending 3 mm or less from the internal auditory canal was much higher than in cases with a larger tumor. Hearing was preserved in three of seven cases with a tumor of 21 mm or larger and in two of four cases of neurofibromatosis type 2. The evaluation of postoperative hearing is also discussed. (*Skull Base Surgery*, 4(2):76–81, 1994)

Hearing preservation has recently become a topic of concern in the treatment of acoustic neuroma for the following reasons: (1) the mortality rate in acoustic neuroma surgery has decreased; (2) the facial nerve preservation rate has improved; (3) more cases are presenting with good hearing because of increased early diagnosis; (4) it is still difficult to preserve hearing in cases of neurofibromatosis type 2 (NF2); and (5) hearing preservation in cases treated with the gamma knife is only temporary and ultimate hearing preservation is still difficult.

We have previously reported on the results of acoustic neuroma surgery carried out by our team of neurotologists and neurosurgeons.¹ In the present article we report on our latest results of acoustic neuroma surgery, especially focused on hearing preservation.

MATERIALS AND METHODS

A total of 248 cases of acoustic neuroma were operated on either by three types of the extended middle cranial fossa (EMCF) approach or by the nonextended middle cranial fossa (MCF) approach during a 16-year period from 1976 to 1991 in Keio University Hospital.

The EMCF approach can be divided into three types as described in our previous communication.² The differences of the three types of the EMCF approach are summarized in Table 1. Hearing is not preserved in types I and II, whereas hearing preservation is intended in type III. Type I and type II are divided according to the degree of enlargement of the surgical field by labyrinthectomy via

Table 1. Classification of the Extended Middle Cranial Fossa Approach (EMCF)*

EMCF Type	Labyrinthectomy	Incision of the Posterior Fossa Dura	Separation of the Superior Petrosal Vein	Incision of the Cerebellar Tentorium
I	Done	Done	Not done	Not done
II	Done	Done	Done	Done
III	Not done	Done	Done	Done
MCF	Not done	Often done	Not done	Not done

*The middle cranial fossa approach (MCF) involves both the modified MCF approach and the MCF approach by House.³ The incision of the posterior fossa dura is often carried out in the modified MCF approach, but not in the MCF approach by House.³

the MCF, the separation of the superior petrosal vein, and the incision of the cerebellar tentorium as necessitated by the size of tumor. Type III is indicated when hearing preservation is a goal of the operation and tumor removal is difficult by the MCF approach of House³ or by the modified MCF approach in which the bone of the internal auditory canal is removed together with the incision of the posterior fossa dura.² Although most of the intracanalicular tumors and tumors extending a few millimeters into the posterior fossa were operated on by the modified MCF approach and only a few tumors by the MCF approach in our series, the term of the MCF approach in the following descriptions of this article includes both the modified and the MCF approach by House.³ The EMCF approach type III combines the MCF approach with the subtemporal transtentorial approach, which involves the separation of the superior petrosal vein and the incision of the cerebellar tentorium.

Hearing preservation was attempted when one of the following conditions was met: (1) three-frequency pure-tone hearing average (500 Hz, 1 kHz, and 2 kHz) was good (as a rule, the 50/50 hearing, that is, pure-tone hearing level of 50 dB and lower and speech discrimination score of 50% or higher); (2) hearing was slightly less than the 50/50 hearing but the tumor was 20 mm or smaller in diameter; and (3) an NF2 patient.

In the present series, hearing preservation was attempted in 69 cases, including four cases of NF2. The average age in the cases of attempted hearing preservation was 47.2 years (15 to 65 years); there were 37 males and 32 females. The MCF approach was applied to 26 cases and the EMCF approach type III to 43 cases. The MCF approach was used when a tumor extended 7 mm or less from the internal auditory canal. The EMCF approach type III was generally used to remove tumors extending more than 7 mm from the internal auditory canal. In some cases with a tumor of less than 7 mm, however, the EMCF approach type III was also applied in order to monitor the eighth nerve compound action potentials on the brainstem side.

Tumor size was determined by measuring diameter along the direction of the internal auditory canal on computed tomography (CT) or magnetic resonance imaging (MRI). In some cases operated on before the introduction of CT, the tumor size was determined by meatomyelography using a contrast medium or air. Among the cases in which the tumor size was determined by meatomyelogra-

phy, hearing preservation was attempted only by the MCF approach when a tumor extended no more than a few millimeters into the posterior fossa.

The numbers of cases with hearing preserved and not preserved are shown according to the tumor size in Table 2. The tumor size was 20 mm or smaller in 62 cases (90%) and 21 mm or larger in 7 cases (10%). The tumors were totally removed in 64 cases (93%) and subtotally in five cases (7%). Among 35 cases with hearing preservation, however, there was total removal in 31 cases (89%) and subtotal removal in four cases (11%), including a case of NF2.

Statistical significance was tested using ANOVA in the present study.

RESULTS

Tumor Size and Hearing Preservation

Among 69 cases of attempted hearing preservation, hearing was preserved in 17 (63%) of 27 cases with a tumor extending 3 mm or less from the internal auditory canal (Table 2). The hearing preservation rate decreased according to the extension of the tumor into the posterior fossa. However, the hearing preservation rate was not significantly higher in the cases with a tumor of 3 mm or less than in those with a larger tumor.

Table 2. Tumor Size and Hearing Preservation in the Entire Series*

Tumor Size (mm)	No. Cases	Hearing Preservation		Hearing Preservation	
		Total Removal	Subtotal Removal	No.	(%)
Intracanalicular tumor					
≤3	27	17	0	17	63
4–10	18	8	0	8	44
11–20	17	5	2	7	41
≥21	7	1	2	3	43
Total	69	31	4	35	51

*Statistical significance was tested by ANOVA.

Surgical Approach and Hearing Preservation

In the present series, tumor removal was carried out either by the MCF approach or the EMCF approach type III (Table 3). Hearing was preserved in 21 (81%) of 26 cases treated by the MCF approach and in 14 (33%) of 43 cases by the EMCF approach type III. The hearing preservation rate was significantly higher by the MCF approach than by the EMCF approach type III ($p < 0.05$).

Tumor Size, Preoperative and Postoperative Hearing, and Hearing Preservation

Among 69 cases in which hearing preservation was attempted, measurable hearing was preserved in 35 cases (51%) (Table 4). In 42 cases with 50/50 hearing and a tumor of 20 mm or smaller in diameter, hearing was preserved in 24 cases (57%). The hearing preservation rate was 76% in the group in which a tumor extended 3 mm or less from the internal auditory canal. This was significantly higher than in those with a tumor extending 4 mm or more into the posterior fossa ($p < 0.05$). Of these, the 50/50 hearing was preserved postoperatively in 17 cases, that is 71% of 24 cases with hearing preservation and 40%

of 42 cases with the 50/50 hearing. On the other hand, among the cases with a tumor of 20 mm or smaller in diameter but less than the 50/50 hearing (that is, pure-tone hearing level of 50 dB or higher or speech discrimination score of less than 50%), hearing was preserved in seven (37%) of 19 cases. Among the cases with a tumor of 20 mm or smaller in diameter, the hearing preservation rate was not significantly higher in those with the 50/50 hearing than in those with less than the 50/50 hearing.

Although there were only four cases either with a tumor of 21 mm or larger in diameter or with NF2, hearing preservation was achieved in 50% of the cases in both groups.

Preoperative Auditory Brainstem Response Findings and Hearing Preservation

The relationship between hearing preservation and preoperative auditory brainstem response (ABR) findings was examined in 55 cases (Table 5). The cases were classified into four types according to the qualitative findings of ABR: identifiable waves I, III, and V; identifiable waves I and V; identifiable wave I, and no response.

Hearing was preserved in 70% of the cases in which waves I, III, and V could be identified preoperatively, which was a significantly higher percentage than in the other groups (waves I and V, wave I only, and no response) in which hearing was preserved in 7 of 25 cases (28%) ($p < 0.01$).

Tumor Origin and Hearing Preservation

The relationship between the origin of the tumor and hearing preservation was examined in 27 cases in which the origin could be determined during operation. The inferior vestibular nerve was identified as a tumor origin

Table 3. Surgical Approach and Hearing Preservation*

	No. Cases	No. NF2 Cases	Hearing Preservation	
			No.	%
MCF	26	1	21	81 [†]
EMCF type III	43	3	14	33
Total	69	4	35	51

*Statistical significance was tested using ANOVA.

[†] $p < 0.05$.

Table 4. Tumor Size, Preoperative and Postoperative Hearing, and Hearing Preservation*

Tumor Size [†] (mm)	Preoperative Hearing [‡]	No. Cases	Hearing Preservation		Postoperative Hearing >50/50 (%)	
			No.	%	No.	%
IC $\leq$ 20	>50/50	42	24	57	17	40
IC $\leq$ 3		17	13	76 [§]		
4–20		25	11	44		
$\geq$ 20	>50/50	4	2	50	1	25
NF2		4	2	50	0	0
IC $\leq$ 20	<50/50	19	7	37	0	0
Total		69	35	51	18	26

*Statistical significance was tested using ANOVA.

[†]IC: intracranial tumor; NF2: neurofibromatosis type 2.

[‡]>50/50 indicates pure-tone hearing level of less than 50 dB and speech discrimination score of more than 50%. <50/50 indicates pure-tone hearing level of more than 50 dB or speech discrimination score of less than 50%.

[§] $p < 0.05$.

Table 5. Preoperative Auditory Brainstem Response (ABR) Findings and Hearing Preservation

ABR Findings	No. Cases	Hearing Preservation*	
		No.	%
Wave I, III, V	30	21	70
Wave I, V	6	2	33
Wave I	11	3	27
No response	8	2	25
Total	55	28	51

*The hearing preservation rate in the Wave I, III, V group was significantly higher than those in the other groups, $p < 0.01$. Statistical significance was tested using ANOVA.

in 21 cases, whereas only six tumors originated from the superior vestibular nerve. The inferior vestibular nerve was easier to be identified as an origin in cases in which the superior vestibular nerve could be observed. Hearing was preserved in 10 (48%) of 21 cases with a tumor of the inferior vestibular nerve origin and in four (67%) of six cases with a tumor originating from the superior vestibular nerve, respectively.

Course of Postoperative Hearing

Among 35 cases with hearing preservation, the follow-up period was 2 years or longer (maximum 16 years) in 24 cases, 1 to 2 years in seven cases, and less than 1 year in four cases.

Postoperative hearing deteriorated within 1 month after the operation in three cases, including a case of NF2. In two cases hearing deteriorated during long-term postoperative follow-up because of the tumor recurrence. In contrast, there has been no recurrence so far for 6 years in the other case in which part of the tumor was left to preserve hearing. In one case of NF2 whose tumor was subtotally removed, hearing has been preserved to date (1.5 years postoperatively) and MRI revealed no increase in tumor size.

Facial Nerve Preservation

The facial nerve was preserved in 37 (97%) of 38 cases of hearing preservation. According to the House-Brackmann's facial nerve grading system, there were 29 cases (85%) of grade I, three cases (9%) of grade II, and two cases (6%) of grade III. No case was classified into grades IV, V, and VI.

DISCUSSION

Among 248 cases in our entire series, hearing preservation surgery was attempted in 69 cases (28%). When the indication for hearing preservation surgery was defined as

a tumor size of 20 mm or less and 50/50 hearing, this applied to only 42 cases (17%). We divided the first 200 cases in our series into the first 100 cases and the second 100 cases. Excluding those cases of reoperation and those with incomplete data, we analyzed the remaining 68 cases in the first half (group I) and 91 cases in the latter half of this series (group II) (Table 6). When the cases were examined for 30/70 hearing (pure-tone hearing level of 30 dB or lower and speech discrimination score of 70% or higher) and 50/50 hearing, the percentage of the cases with 30/70 hearing becomes doubled in group II but the percentage of the cases with 50/50 hearing increases only slightly. Although these statistics do not take tumor size into account, the incidence of the candidates for hearing preservation (30%) corresponds to the actual rate of hearing preservation surgery (28%) in the present series. If the indication for hearing preservation surgery is set at 30/70 hearing, however, only a few cases would still be eligible for hearing preservation surgery. Therefore, we believe that at the present stage, 50/50 hearing is a suitable indication, especially if we are to pursue further the possibilities of hearing preservation in acoustic neuroma surgery. Just as the rate of facial nerve preservation improved with experience, the rate of hearing preservation should also improve with experience.

The percentage of cases with hearing preserved in any particular series no doubt differs according to sample size, incidence of early-staged tumors, and the surgeon's philosophy regarding hearing preservation. In the literature,⁴⁻¹⁰ this percentage ranges from 1 to 18% (Table 7). In our series, hearing preservation was achieved in 35 of 248 cases (14%). On the other hand, the successful hearing preservation rate among the cases of attempted hearing preservation surgery ranges from 20 to 51%. The successful hearing preservation rate in the present series (51%) is comparable to that reported with the MCF, suboccipital or retrosigmoid approach.^{4,9,11} Postoperatively, 50/50 hearing was preserved in 2 to 18 cases (18 cases in the present series). This was only a small percentage of the entire series and only 12 to 31% of those in which hearing preservation had been attempted (26% in the present series).

Among the cases with a tumor extending 3 mm or

Table 6. Changes in Percentage of Cases with Serviceable Hearing*

	Group I† (n = 68)		Group II† (n = 91)		Total (n = 159)	
	No.	%	No.	%	No.	%
PTA ≤ 30 dB, SDS ≥ 70%	7	10	20	22	27	17
PTA ≤ 50 dB, SDS ≥ 50%	17	25	30	33	47	30

*PTA: pure-tone hearing average; SDS: speech discrimination score.

†Group I consists of early cases and group II of late cases in our sequential series.

Table 7. Results of Hearing Preservation Surgery in Various Reports

Reference	Approach*	Total Cases	Attempted Hearing Preservation	Successful Hearing Preservation	Postoperative Hearing (>50/50) [†]
Nadol et al ⁴	SO		69	29	15
Glasscock et al ⁵	MCF, SO	659	47	17	
Sanna et al ⁶	MCF, SO	220	34	14	4
Gardner and Robertson ⁷	MCF, SO	160	10	2	2
Helms et al ⁸	MCF	136	41	12	
Baldwin et al ⁹	SO	109	45	20	14
Harner et al ¹⁰	RS	332		4	14
Kanzaki et al ¹⁴	MCF, EMCF	248	69	35	18

*SO: suboccipital approach; MCF: middle cranial fossa approach; RS: retrosigmoid approach; EMCF: extended middle cranial fossa approach.

[†]>50/50 indicates pure-tone hearing level of less than 50 dB and speech discrimination score of more than 50%.

less from the internal auditory canal, hearing was preserved in 63% of the entire cases and in 76% of those with 50/50 hearing. However, the hearing preservation rate did not differ remarkably among those with a tumor extending 4 mm or more into the posterior fossa, being as high as 43% as a whole and 44% among the 50/50 cases. Glasscock et al,⁵ Shelton et al,¹² and others who have mostly used the MCF approach have reported that the hearing preservation rate is higher in smaller tumors. Shelton et al¹² reported that the hearing preservation rate was 80% by the MCF approach among those cases with a tumor of 5 mm or less in diameter. This percentage is comparable to the results of the present series. This unexpectedly high rate of hearing preservation in the MCF approach may be due to the fact that the approach was used only for those who had a tumor located within the internal auditory canal.

In the present series, hearing preservation was achieved by the MCF approach in 21 of 26 patients (81%), whereas hearing was preserved by the EMCF approach type III in only 14 of 43 cases (33%). The reason for the lower success rate in the EMCF approach type III may be that this approach was used mainly for a tumor extending more than 8 mm into the posterior fossa. Except surgeons (mostly neurosurgeons) who use the suboccipital or retrosigmoid approach for tumors of any size, most neurotologists use the MCF approach or the suboccipital approach only for hearing preservation surgery according to the size of tumor.^{6,7} One of the advantages of our EMCF approach is that there is no need to select an approach with regard to the tumor size or hearing preservation. The MCF approach and the EMCF approach type III can be applied to smaller tumors or hearing preservation surgery, and the EMCF approach types II and III can be used for larger tumors or patients without serviceable hearing.

There is a discrepancy among previous reports on whether the prognosis for postoperative hearing is related to the tumor size, preoperative speech discrimination score, or ABR findings. Shelton et al,¹² Josey et al,¹³ and Kanzaki et al¹⁴ have found that the success of hearing preservation could be somewhat expected from the tumor

size, preoperative speech discrimination score, or ABR findings, whereas others, such as Kemink et al¹¹ and Kveton,¹⁵ have not. As in our previous report,¹⁴ we found that the prognosis for hearing was better in the cases with a small tumor, serviceable hearing, or with clearly identifiable ABR waves I, III, and V. These findings may indicate less damage to the cochlear nerve. However, no relationship between the prognosis and tumor origin was observed. Even if these factors affecting the prognosis for hearing are identical, the anatomic relationship between the tumor, the cochlear nerve, and the internal auditory artery is variable in every case. These anatomic variations may affect the result of hearing preservation.

With the increase in reports on hearing preservation, a need has developed for a common system for the evaluation of surgical results. It has been suggested that hearing itself should be evaluated by a combination of pure-tone audiometric findings and speech discrimination score.^{7,16} In our previous communication, we proposed that data on the following ten items should be given for consistent evaluation¹⁴: (1) surgical approach; (2) the total number of cases; (3) the incidence of tumors extending 20 mm or less into the posterior fossa; (4) the number of cases of attempted hearing preservation; (5) the number of cases with hearing preserved; (6) the number of cases with 50/50 hearing preoperatively; (7) the number of cases with a tumor of 20 mm in diameter or smaller and 50/50 hearing postoperatively; (9) the number of cases with a tumor of 20 mm in diameter or smaller preoperatively and the 50/50 hearing postoperatively; and (10) the duration of postoperative follow-up. Unfortunately, only a few studies have given the information in all these categories. Thus, the common system for the evaluation of hearing preservation surgery should be further discussed and established.

Finally, the results obtained in this study indicate that the further improvements and advances in early diagnosis, surgical techniques, intraoperative monitoring, and preoperative determination of prognosis are necessary for the improvement of the hearing preservation rate in acoustic neuroma surgery.

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