FACIAL AND COCHLEAR NERVE FUNCTION AFTER SURGERY OF CEREBELLOPONTINE ANGLE MENINGIOMAS

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OBJECTIVE: Meningiomas of the cerebellopontine angle (CPA) share a common location, but their site of dural origin and their relationship to surrounding neurovascular structures of the CPA are variable. The clinical presentation and outcome after surgical resection are different because of the diversity of this tumor entity. We report on a series of 421 patients with CPA meningiomas, with special emphasis on the analysis of the preoperative and postoperative facial and cochlear nerve function in relation to the site of dural attachment and main tumor location in the CPA cistern.

METHODS: Among 421 patients, the charts of 347 patients with complete clinical data, including the history and audiograms, imaging studies, surgical records, discharge letters, histological records, and follow-up records, were reviewed retrospectively. Data about preoperative and postoperative facial nerve function were available in 334 patients, and audiometric analysis was conducted in 333 patients. Patients with neurofibromatosis Type 2 were excluded from the study.

RESULTS: There were 270 women and 77 men, with a mean age of 53.4 years (range, 17.6–84 yr). Among these patients, 32.9% of the tumors originated at the petrous ridge anterior to the inner auditory canal (IAC) (Group 1), 22.2% showed involvement of the IAC (Group 2), 20.2% were located superior to the IAC (Group 3), 11.8% were inferior to the IAC (Group 4), and 12.9% were posterior to the IAC, originating between the IAC and the sigmoid sinus (Group 5). Patients presented with disturbance of Cranial Nerves V–VIII, the lower cranial nerves, and ataxia, depending on the main tumor location. Tumor resection was performed through a suboccipital-retrosigmoidal approach in the semisitting position in 95% of the patients. A combined supratentorial-infratentorial presigmoidal approach was performed in 5%. Total tumor removal (Simpson Grade 1 and 2) was achieved in 85.9% and subtotal removal in 14.1%. The best initial postoperative facial and auditory nerve function was observed in tumors belonging to Groups 3 and 5. Recovery from preoperative deafness was observed in 1.8% of patients. On long-term follow-up, good facial nerve function (House-Brackmann Grade 1 or 2) was observed in 88.9% of patients. Hearing preservation among patients with preoperative functional hearing was documented in 90.8% on long-term follow-up.

CONCLUSION: Although the outcome of facial and cochlear nerve function is different in CPA meningiomas, depending on the topographic classification of these tumors, preservation of the cochlear nerve is possible in every tumor group and should be attempted in every patient with CPA meningioma. It has to be kept in mind that recovery of hearing was also observed in patients with preoperative profound hearing deficits.

KEY WORDS: Cerebellopontine angle, Cochlear nerve, Facial nerve, Meningioma

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Meningiomas are common tumors, accounting for 14 to 18% of intracranial neoplasms. They are the second most common tumors of the cerebellopontine angle (CPA) after acoustic neuromas, affecting 6 to 15% of patients (3, 19, 34).

The first report of a tumor that is classified as a CPA meningioma was by Rokitansky in 1856 (23). Virchow (36) later described a psammoma originating from the posterior lip of the meatus acusticus. In 1928, Cushing and Eisenhardt (5) reported on seven patients with

meningiomas "simulating acoustic neuromas," emphasizing the high surgical risk in dealing with these tumors. Several surgical series of posterior fossa meningiomas involving the CPA have been reported since then (8, 13, 15, 22, 24, 31). Microsurgical series were reported by Yaşargil et al. (38), Sekhar and Janetta (32), Ojemann (21), Al-Mefty et al. (1), Haddad and al-Mefty (11), Harrison and al-Mefty (12), Matthies et al. (17), Samii and Ammirati (25, 26), and Samii et al. (28). The term *CPA meningioma* has been used widely to describe meningiomas that share a common location, that is, occupancy of the CPA, although these tumors may have diverse origins with regard to the site of dural attachment, which can be outside the CPA. Therefore, the relationship of the tumor to surrounding neurovascular structures, especially the facial and cochlear nerves, can be quite variable (17, 25, 28, 30, 37).

It has been shown that the clinical presentation and outcome differ between CPA meningiomas lying anterior or posterior to the inner auditory canal (IAC) (25, 30). The aim of this retrospective study is to determine the influence of the tumor location related to the IAC in all directions with regard to the preoperative and postoperative facial and cochlear nerve function. This report presents the results of a large series of microsurgically treated CPA meningiomas.

PATIENTS AND METHODS

A total of 1800 patients with meningiomas were operated on at the Nordstadt Hospital between 1978 and 2002. Among them, there were 421 CPA meningiomas. Patients with neurofibromatosis Type 2 were excluded from the study (n = 19). In 347 patients, complete preoperative and postoperative clinical and neuroradiological data could be acquired. In these patients, the hospital charts, including surgical records, discharge letters, histological records, follow-up records, and imaging studies, were analyzed retrospectively.

A female preponderance was observed, with 270 women (77.8%) compared with 77 men (22.2%). The mean age of the patients was 53.4 years (range, 17.6–84 yr). Before surgery, all patients underwent a general neurological examination, audiological testing with pure tone audiogram and speech discrimination score, and neuroradiological examinations (with computed tomography or magnetic resonance imaging [MRI]).

The preoperative and postoperative facial nerve function was examined according to the House-Brackmann (H-B) grading system (14). Data were available in 334 patients. Preoperative and postoperative hearing function was graded according to the Hannover Audiological Classification in steps of 20 dB of hearing loss, calculated as the mean of air conduction data at 1, 1.5, 2, and 3 kHz in the pure tone audiogram (Class H1, good, 0–20 dB; H2, useful, 21–40 dB; H3, moderate, 41–60 dB; H4, poor, 61–80 dB; and H5, functional deafness, >81 dB) (16). The best speech discrimination score for each patient was classified as normal (100–95%), useful (90–70%), moderate (65–40%), poor (35–5%), or nonexistent (<5%). Complete audiological data were available in 333 patients. The patients were evaluated immediately before surgery and 10 to 14 days postoperatively. The mean follow-up time was 62.3 months (range, 2–214 mo).

The preoperative and postoperative status of the facial and cochlear nerve function was compared among groups by use of the χ^2 test with one degree of freedom. A P value was calculated for each comparison, with significance assumed at the 0.05 level.

RESULTS

Tumor Location

One hundred fourteen CPA meningiomas (32.9%) originated at the petrous ridge anterior to the IAC (Group 1, *Fig. 1, A* and *B*), 77 tumors (22.2%) showed involvement of the IAC (Group 2, *Fig. 2, A* and *B*), 70 tumors (20.2%) originated superior to the IAC (Group 3, *Fig. 3, A* and *B*), 41 tumors (11.8%) were inferior to the IAC (Group 4, *Fig. 4, A* and *B*), and 45 tumors (12.9%) were posterior to the IAC, originating between the IAC and sigmoid sinus (Group 5, *Fig. 5, A* and *B*).

Nerve-Tumor Relationship

Among 42 documented cases of Group 1 tumors, the facial and cochlear nerves were most commonly displaced posteriorly (45.2%) (*Fig. 1B*); inferior displacement was observed in 42.9% and superior displacement in 9.5%. The trigeminal nerve was displaced primarily superiorly (59.5%), anterior displacement was observed in 26.2%, and inferior displacement was seen in 14.3%. Cranial Nerves IX–XI were displaced inferiorly in only 16.7% of patients.

A nerve-tumor relationship was documented in 48 patients with Group 2 tumors. The facial and cochlear nerves were most commonly surrounded by the tumor (29.2%) (*Fig. 2B*); displacement in the superior (25%) and inferior (25%) directions was also observed. Posterior (12.5%) and anterior (8.3%) displacement was less common. In large tumors, the trigeminal nerve was displaced superiorly in 16.7% of patients. Cranial Nerves IX–XI were displaced inferiorly in 29.2% of patients.

Among 36 documented cases of Group 3 tumors, the facial and cochlear nerves were most commonly displaced inferiorly (77.8%) (*Fig. 3B*); anterior displacement was observed in only 16.7%. The trigeminal nerve was displaced inferiorly in large tumors in 33.3% of patients (*Fig. 3B*).

In Group 4 tumors, a nerve-tumor relationship was documented in 32 patients. In 68.75%, the facial and cochlear nerves were displaced superiorly (*Fig. 4B*); anterior displacement was observed in 18.75%. In 68.75% of patients, the trigeminal nerve was not involved, but in large tumors, displacement was observed in the superior direction in 25%. Cranial Nerves IX–XI were displaced inferiorly in 56.25% of patients (*Fig. 4B*).

Among 24 documented cases of Group 5 tumors, the facial and cochlear nerves were displaced anteriorly in 62.5% (*Fig.*

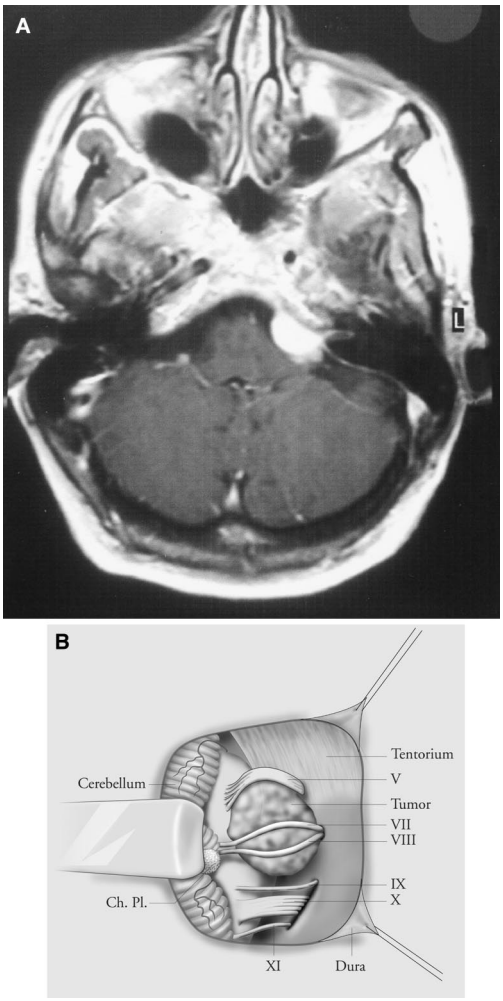

FIGURE 1. A, *MRI scan showing example of a Group 1 tumor in a 58-year-old woman with left-sided CPA meningioma located anterior to the IAC.* B, *illustration of a Group 1 tumor displacing the facial* (VII) *and cochlear* (VIII) *nerves posteriorly (45.2%) and compressing the trigeminal nerve* (V) *superiorly (59.5%). An inferior displacement of the facial* (VII) *and cochlear* (VIII) *nerves was observed in 42.9% (not shown in illustration).* Ch. Pl., *choroid plexus;* IX, *glossopharyngeal nerve;* X, *vagus nerve;* XI, *accessory nerve.*

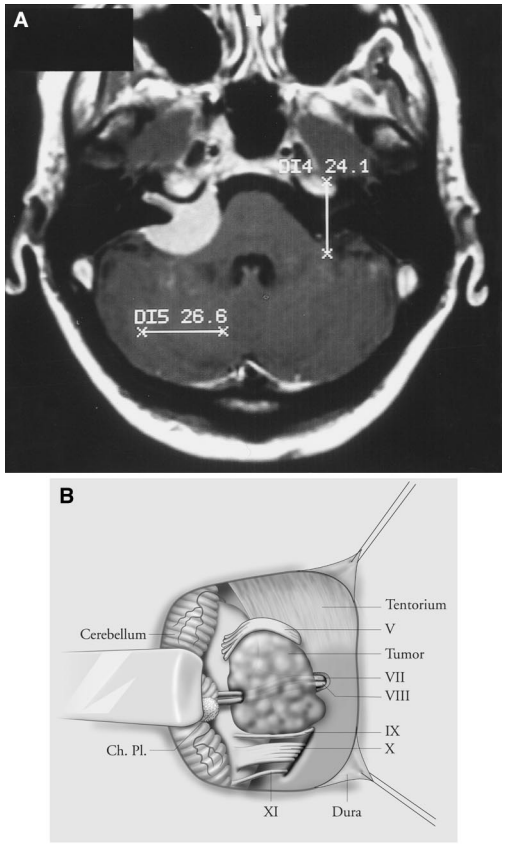

FIGURE 2. A, *MRI scan showing example of a Group 2 tumor in a 44-year-old woman with right-sided CPA meningioma involving the IAC.* B, *illustration of a Group 2 tumor involving the IAC. The posterior wall of the IAC is removed. The tumor may either originate in the IAC or involve the IAC secondarily. The facial* (VII) *and cochlear* (VIII) *nerves lay within the tumor in 29.2% of cases. Superior or inferior displacement was observed in 25% each (not shown). The majority of tumors (70.8%) did not displace the trigeminal nerve* (V), *but in larger tumors, the displacement was observed primarily to the superior (16.7%) and anterior (8.3%) directions.* Ch. Pl., *choroid plexus;* V, *trigeminal nerve;* IX, *glossopharyngeal nerve;* X, *vagus nerve;* XI, *accessory nerve.*

5B), and inferior displacement was observed in 25%. There was no relation to the trigeminal nerve in 87.5% of patients, and anterior displacement was observed in large tumors in 12.5% of patients. Cranial Nerves IX–XI were most commonly displaced in the inferior direction (50%); they were equally displaced anteriorly or had been surrounded by the tumor in 12.5%.

Tumor Resection

Three hundred thirty patients were operated on through a lateral suboccipital retrosigmoidal approach with the patient in the semisitting position. The surgical technique has been described previously in detail (25). In 17 patients with tumors extending anterior to the petroclival region, a combined supratentorial-infratentorial presigmoidal approach was performed. Among them, 10 tumors were classified as Group 1, 3 tumors as Group 2, and 4 tumors as Group 3.

Intraoperative neuromonitoring of the facial and the cochlear nerves has been available since 1986, and standardized protocols have been used routinely since 1990 (Medelec, Ltd., Surrey, England). The intracranial part of the surgery was performed under the operating microscope.

The extent of tumor resection was classified according to Simpson (33). Total tumor resection, including Simpson Grades 1 and 2, could be achieved in 95 tumors (83.3%) in Group 1, 68 tumors (88.3%) in Group 2, 63 tumors (90%) in Group 3, 32 tumors (78%) in Group 4, and 40 tumors (88.9%)

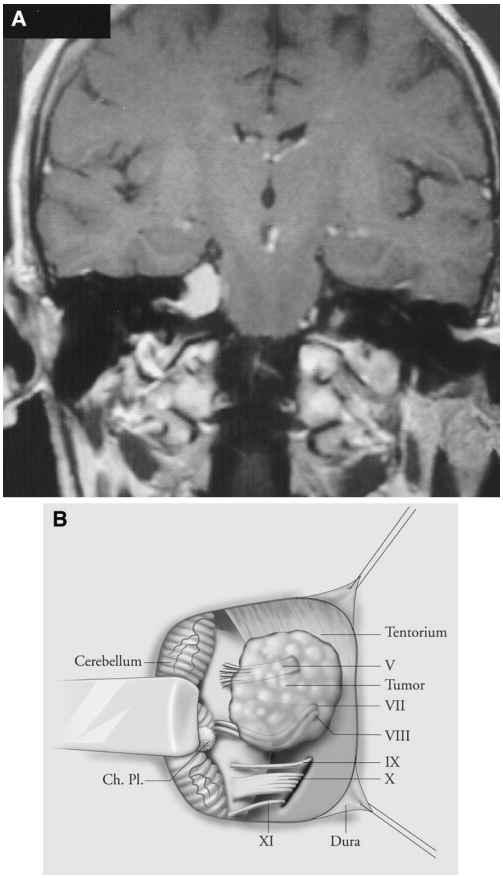

FIGURE 3. A, *MRI scan showing example of a Group 3 tumor in a 58-year-old woman with right-sided CPA meningioma located superior to the IAC.* B, *illustration of a Group 3 tumor displacing the facial* (VII) *and cochlear nerves* (VIII) *inferiorly and compressing the trigeminal nerve inferiorly. Inferior displacement of the facial* (VII) *and cochlear nerves* (VIII) *was observed in 77.8%; the trigeminal nerve was most commonly displaced inferiorly in large tumors (33.3%).* Ch. Pl., *choroid plexus;* V, *trigeminal nerve;* IX, *glossopharyngeal nerve;* X, *vagus nerve;* XI, *accessory nerve.*

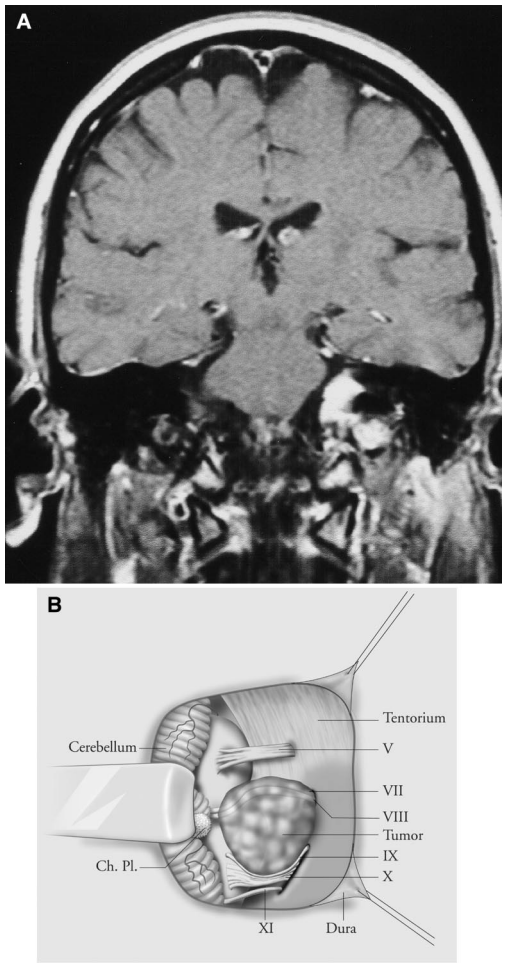

FIGURE 4. A, *MRI scan showing example of a Group 4 tumor in a 45-year-old woman with left-sided CPA meningioma located inferior to the IAC.* B, *illustration of a Group 4 tumor displacing the facial* (VII) *and cochlear nerves* (VIII) *anterosuperiorly (68.75%) and compressing the glossopharyngeal* (IX) *and vagus* (X) *nerves inferiorly (56.25%).* Ch. Pl., *choroid plexus;* V, *trigeminal nerve;* XI, *accessory nerve.*

in Group 5. Altogether, 85.9% of patients underwent complete tumor resection and 14.1% a subtotal removal of the tumor.

In the subgroup of patients who underwent tumor resection through the combined supratentorial-infratentorial presigmoidal approach, total tumor removal was achieved in 12 (70.58%) of 17 patients, and in 5 patients, a subtotal removal was performed because of involvement of the cavernous sinus.

Complications

The most common complication was cerebrospinal fluid fistula and postoperative hydrocephalus in 16 patients (4.6%) each. Ten patients with cerebrospinal fluid fistula required temporary lumbar drainage (2.8%), and 3 patients underwent surgical revision (0.8%). Eleven patients (3.2%) with hydrocephalus required temporary external ventricular drainage, and 5 patients (1.4%) finally needed a ventriculoperitoneal shunt (1 patient among them was operated on via the combined approach). Eight patients (2.3%) required a tracheostomy to prevent aspiration because of disturbance of the lower cranial nerves. A postoperative hemorrhage occurred in 12 patients (3.5%), requiring surgical evacuation in 9 patients (2.6%). A sigmoid sinus thrombosis occurred in 1 patient each who were treated with a lateral suboccipital approach (0.3%) and a combined supratentorial-infratentorial presigmoidal approach (5.8%).

Two patients (0.6%) died perioperatively, 1 as a result of aspiration on the third postoperative day (following a combined supratentorial-infratentorial presigmoidal approach) and the other as a result of a hematoma on the second day after surgery following tumor removal through the lateral suboccipital approach.

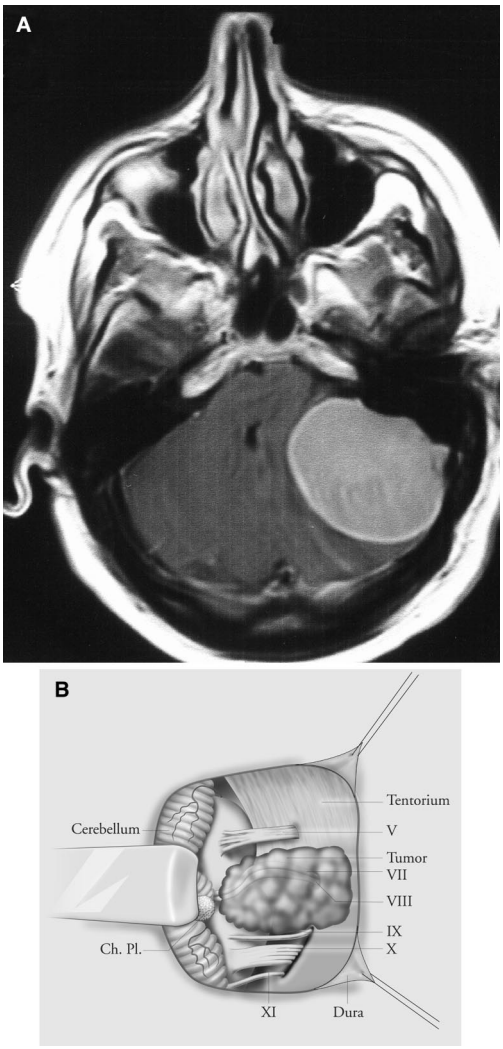

FIGURE 5. A, *MRI scan showing example of a Group 5 tumor in a 46-year-old woman with left-sided CPA meningioma located posterior to the IAC.* B, *illustration of a Group 5 tumor displacing the facial (*VII*) and cochlear nerves (*VIII*) anteriorly (62.5%). Inferior displacement of these nerves was observed in 25% (not shown). The glossopharyngeal (*IX*) and vagus (*X*) nerves were displaced inferiorly in 50% (not shown).* Ch. Pl., *choroid plexus;* V, *trigeminal nerve;* IX, *glossopharyngeal nerve;* X, *vagus nerve;* XI, *accessory nerve.*

Facial Nerve Function

The results of the preoperative and postoperative facial nerve function were available on 334 patients. In Group 1 tumors, the facial nerve function of 109 patients was evaluated. Most of the patients (n = 93, 85.3%) presented initially with no facial paresis (H-B Grade 1). There were 9 patients (8.3%) with H-B Grade 2 paresis, 3 patients (2.8%) with H-B Grade 3 paresis, 2 patients (1.8%) with H-B Grade 4 paresis, and 2 patients (1.8%) with complete facial paresis. Both patients with preoperative complete facial palsy had already been operated on in an outside hospital and presented with a recurrent tumor. Postoperative results are presented in *Figure 6*.

In Group 2 tumors involving the IAC, the facial nerve function of 76 patients was evaluated. Most of the patients presented with no facial nerve paresis preoperatively (n = 62, 81.6%). Five patients (6.6%) presented with a facial nerve paresis of H-B Grade 2 score, 3 patients (3.9%) with H-B Grade 3 score, 3 patients (3.9%) with H-B Grade 4 score, 2 patients (2.6%) with H-B Grade 5 score, and 1 patient (1.3%) with complete facial nerve paresis. Postoperative results are presented in *Figure 7*.

In Group 3 tumors, preoperative and postoperative facial nerve function could be evaluated in 66 patients. There were 58 patients (87.9%) presenting without any facial nerve deficit. Seven patients (10.6%) presented with a facial nerve paresis of H-B Grade 2 score and 1 patient (1.5%) with previous surgery and complete facial nerve palsy. Postoperative results are presented in *Figure 8*.

In Group 4 tumors, preoperative and postoperative facial nerve function could be evaluated in 39 patients. Thirty-one patients (79.5%) presented without any facial nerve paresis (H-B Grade 1), 5 patients (12.8%) had a mild facial nerve paresis of H-B Grade 2, 2 patients (5.1%) presented with an H-B Grade 3 score, and 1 patient (2.6%) presented with an H-B Grade 4 score. Postoperative results are presented in *Figure 9*.

Among patients with Group 5 tumors, preoperative and postoperative facial nerve function could be evaluated in 44 patients, 40 patients (90.9%) presented without any facial

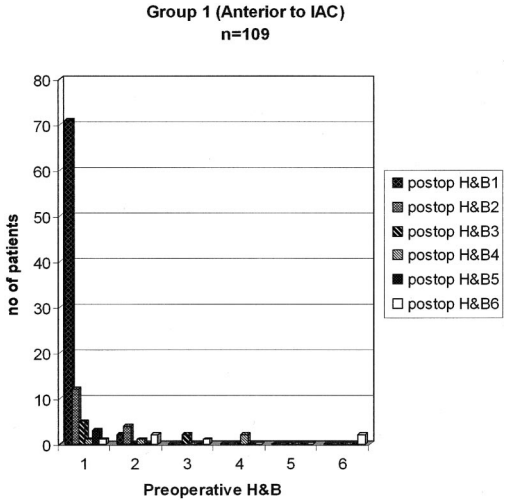

FIGURE 6. *Graph showing preoperative and postoperative (*postop*) facial nerve function in 109 CPA meningiomas located anterior to the IAC (Group 1). The number of patients is presented according to their grade of facial nerve function before and after surgery. Of 93 patients, 71 (76.3%) maintained an H-B Grade 1 score after surgery, 2 patients improved from H-B Grade 2 to Grade 1, 4 (44.4%) of 9 patients maintained an H-B Grade 2 score, 2 (66.6%) of 3 patients retained H-B Grade 3 score, 2 (100%) remained H-B Grade 4, and both patients with preoperative complete facial palsy remained the same, as expected. In other patients, facial nerve function deteriorated in the immediate postoperative period.* H&B, *H-B grade.*

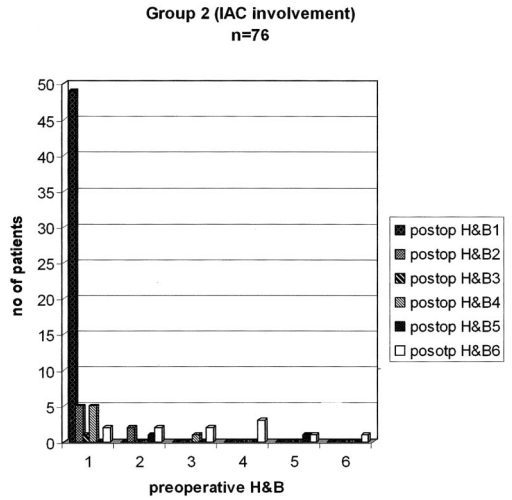

FIGURE 7. *Graph showing preoperative and postoperative* (postop) *facial nerve function in 76 CPA meningiomas involving the IAC (Group 2). The number of patients is presented according to their grade of facial nerve function before and after surgery. Of 62 patients, 49 (79%) maintained H-B Grade 1 score immediately after surgery, 2 (40%) of 5 patients maintained H-B Grade 2 score, and 1 (50%) of 2 patients remained at an H-B Grade 5 score. In other patients, facial nerve function deteriorated in the initial postoperative period.* H&B, *H-B grade.*

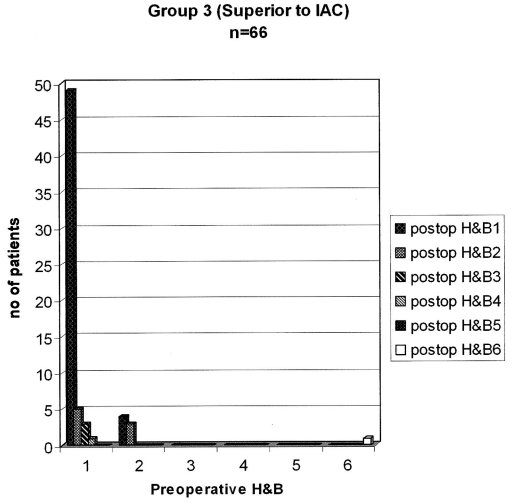

FIGURE 8. *Graph showing preoperative and postoperative* (postop) *facial nerve function in 66 CPA meningiomas located superior to the IAC (Group 3). The number of patients is presented according to their grade of facial nerve function before and after surgery. Of 58 patients, 49 (84.5%) maintained H-B Grade 1 after surgery and 4 improved from H-B Grade 2 to Grade 1 score in the immediate postoperative period. Three (42.9%) of 7 patients maintained an H-B Grade 2 score, and the patient presenting with complete facial palsy remained the same after surgery. In the other few patients, deterioration of facial nerve function was observed.* H&B, *H-B grade.*

nerve deficit (H-B Grade 1), and 4 patients (9.1%) had a mild facial nerve paresis before surgery (H-B Grade 2). Postoperative results are presented in *Figure 10*.

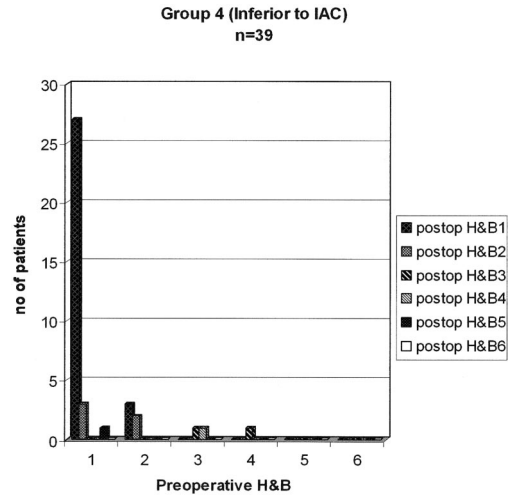

FIGURE 9. *Graph showing preoperative and postoperative* (postop) *facial nerve function in 39 CPA meningiomas located inferior to the IAC (Group 4). The number of patients is presented according to their grade of facial nerve function before and after surgery. Of 31 patients, 27 (87%) maintained an H-B Grade 1 score after surgery, 3 patients showed improvement of facial nerve function from H-B Grade 2 to Grade 1, 2 (40%) of 5 patients retained H-B Grade 2 score, 1 (50%) of 2 patients maintained H-B Grade 3 score, and the patient with preoperative H-B Grade 4 score improved to Grade 3 postoperatively. In 5 patients, deterioration of postoperative facial nerve function was observed.* H&B, *H-B grade.*

Comparison among groups showed that preoperative facial nerve paresis was less common in patients with Group 5 tumors (9.1%) compared with Group 4 (20.5%) and Group 2 (18.4%), although the difference was not statistically significant (Group 5 versus 4, $P = 0.1397$; Group 5 versus 2, $P = 0.1678$). The immediate postoperative result of facial nerve function in patients with preoperative good function is best in Group 5 (preservation of H-B Grade 1 score in 90%), followed by Group 4 (preservation of H-B Grade 1 score in 87%) and Group 3 (preservation of H-B Grade 1 score in 84.5%). Preservation of preoperative good facial nerve function was less common in Group 1 (76.3% H-B Grade 1 score) and in Group 2 (79% H-B Grade 1 score) tumors, although it was still achieved in the majority of patients (*Table 1*). The difference between Groups 5 and 1 was statistically significant at a value of $P = 0.0414$; the difference between Groups 5 and 2 did not reach statistical significance ($P = 0.1467$).

Improvement of facial nerve function in the immediate postoperative period was observed in all four patients with Group 5 tumors presenting with a mild paresis (H-B Grade 2). Recovery from mild facial paresis was also observed in other groups. Improvement from H-B Grade 2 to Grade 1 was observed in four (57.1%) of seven patients in Group 3, in three (60%) of five patients in Group 4, and in two (22.2%) of nine patients in Group 1. No improvement of facial nerve function in the immediate postoperative period was observed in patients with tumors involving the IAC (Group 2).

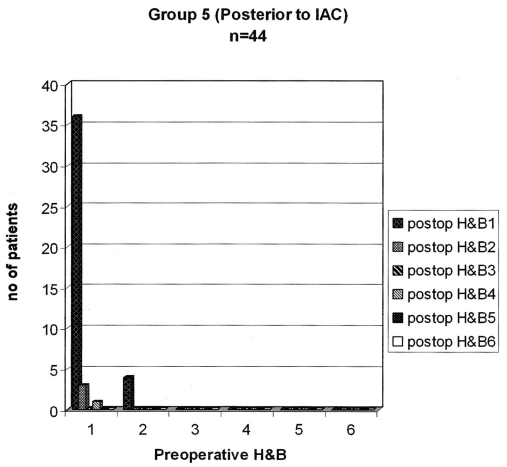

FIGURE 10. *Graph showing preoperative and postoperative* (postop) *facial nerve function in 44 CPA meningiomas located posterior to the IAC (Group 5). The number of patients is presented according to their grade of facial nerve function before and after surgery. Of 40 patients, 36 (90%) maintained an H-B Grade 1 score after surgery, and all 4 patients with preoperative H-B Grade 2 score improved to Grade 1 immediately after surgery. In only 1 patient was a deterioration of facial nerve function observed from preoperative H-B Grade 1 to Grade 4; in 3 patients without preoperative facial nerve deficit, a mild paresis of H-B Grade 2 was observed after surgery.* H&B, *H-B grade.*

The outcome of facial nerve function depending on the surgical approach did not reveal any significant difference. Twelve (70.6%) of 17 patients (Group 1, 2, and 3 tumors) who were operated on through the combined supratentorial-infratentorial approach had no preoperative facial nerve paresis (H-B Grade 1). Ten (83.3%) of these 12 patients had preservation of normal facial nerve function. Among 234 patients with Group 1 to 3 tumors who underwent surgery through the lateral suboccipital approach, 201 patients (85.9%) had no preoperative facial nerve paresis (H-B Grade 1). Of these 201 patients, 159 (79.1%) had preservation of facial nerve function on the same level after surgery. There was no statistically significant difference concerning facial nerve outcome between the two approaches ($P = 0.7252$).

The influence of tumor size as a possible relevant factor for facial nerve outcome was examined. There were 149 tumors (44.6%) with a diameter of 3 cm or less; 129 patients (86.6%) among them had normal preoperative facial nerve function (H-B Grade 1). In 107 patients (82.9%), normal facial nerve function was preserved postoperatively. One hundred eighty-five patients (55.4%) had tumors >3 cm. Among them, 155 patients 83.8%) had normal preoperative facial nerve function (H-B Grade 1). Of these, 125 (80.6%) had preservation of normal facial nerve function after surgery. Statistical comparison did not reveal any significant difference concerning facial nerve outcome between the two groups ($P = 0.6177$).

The relationship between the extent of tumor resection and facial nerve function was investigated. Forty-eight tumors were subtotally resected. Among them, 32 patients (66.7%) had normal preoperative facial nerve function (H-B Grade 1). In 25 patients (78.1%), facial nerve function was preserved on the same level after surgery. Total tumor resection was achieved in 286 patients. Normal preoperative facial nerve function was observed in 252 patients (88.1%). In 207 patients (82.1%), preservation of facial nerve function on the same level was possible. Statistical comparison did not show any significant difference between the two groups ($P = 0.5799$).

Tumors with intrameatal involvement (Group 2 tumors) were analyzed separately. Among 76 tumors, 9 were subtotally removed. Among them, 5 patients (55.6%) presented with normal facial nerve function (H-B Grade 1). All 5 patients (100%) had preservation of normal function after surgery. Sixty-seven patients underwent total resection; among them, 57 patients (85.1%) had normal facial nerve function (H-B Grade 1). Forty-four patients (77.2%) had preservation of facial nerve function at the same level postoperatively. Because of the small number of patients presenting with normal facial nerve function in the group with subtotal tumor resection, statistical comparison did not reveal any significant difference between the two groups ($P = 0.2297$).

Auditory Function

Results of preoperative and postoperative auditory function based on pure tone audiogram and speech discrimination tests could be obtained in 333 patients. In Group 1 tumors, only 49 (45%) of 109 patients had normal hearing preoperatively (Class H1). Seventeen patients (15.6%) presented with Class H2 hearing, 19 patients (17.4%) with Class H3 hearing, 13 (11.9%) with Class H4 hearing, and 11 (10.1%) were already deaf (Class H5). Postoperative results are presented in *Figure 11*.

In Group 2 tumors, only 22 (28.9%) of 76 patients presented with normal hearing (Class H1) before surgery. Seventeen patients (22.4%) had Class H2 hearing, 14 (18.4%) had Class H3 hearing, 6 (7.9%) had Class 4 hearing, and 17 (22.4%) were already functionally deaf at the time of surgery (Class H5). Postoperative results are presented in *Figure 12*.

In Group 3 tumors, 32 (49.2%) of 65 patients had normal hearing (Class H1) before surgery. Twelve patients (18.5%) had Class H2 hearing, 10 (15.4%) had Class 3 hearing, 3 (4.6%) presented with Class 4 hearing, and 8 (12.3%) were already deaf before surgery. Postoperative results are presented in *Figure 13*.

In Group 4 tumors, 11 (28.2%) of 39 patients presented with normal hearing (Class H1) before surgery. Ten patients (25.6%) had Class H2 hearing, 4 each (10.3%) presented with Class H3 and H4 hearing, and 10 (25.6%) were already deaf on the affected side before surgery. Postoperative results are presented in *Figure 14*.

In Group 5 tumors, 21 (47.7%) of 44 patients presented with normal hearing (Class H1) before surgery. Ten (22.7%) patients had Class H2 hearing, 7 (15.9%) presented with Class H3 hearing, and 3 (6.8%) presented with Class H4 hearing. Three

TABLE 1. Rate of functional facial nerve preservation on the same preoperative level after surgery (including improvements)[a]

	Group 1	Group 2	Group 3	Group 4	Group 5
H-B1	71/93 (76.3%)	49/62 (79%)	49/58 (84.5%)	27/31 (87%)	36/40 (90%)
H-B2	6/9 (66.6%)	2/5 (40%)	7/7 (100%)	5/5 (100%)	4/4 (100%)
H-B3	2/3 (66.6%)	0/3 (0%)		1/2 (50%)	

[a] H-B, House-Brackmann grade.

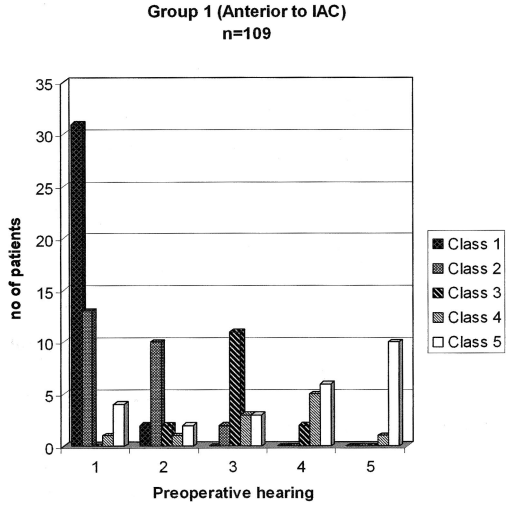

FIGURE 11. *Graph showing preoperative and postoperative auditory function in 109 CPA meningiomas located anterior to the IAC (Group 1). The number of patients is presented according to their grade of hearing deficit before and after surgery. Of 49 patients, 31 (63.3%) maintained normal hearing after surgery (Class H1), 2 patients with preoperative class H2 hearing improved to normal hearing (Class H1), and altogether, 12 (70.6%) of 17 patients retained at least Class H2 hearing after surgery. Two patients with preoperative Class H3 hearing improved to Class H2 hearing, and altogether, 13 (68.4%) of 19 patients maintained at least the same level of hearing (Class H3 or better) after surgery. Two patients improved from Class H4 hearing to Class H3 hearing after surgery. Among 13 patients with preoperative Class H4 hearing, 7 (53.8%) retained at least the same level of hearing after surgery. One patient recovered from preoperative functional deafness to Class H4 hearing after surgery; the others remained deaf. Hearing function was graded according to the Hannover Audiological Classification.*

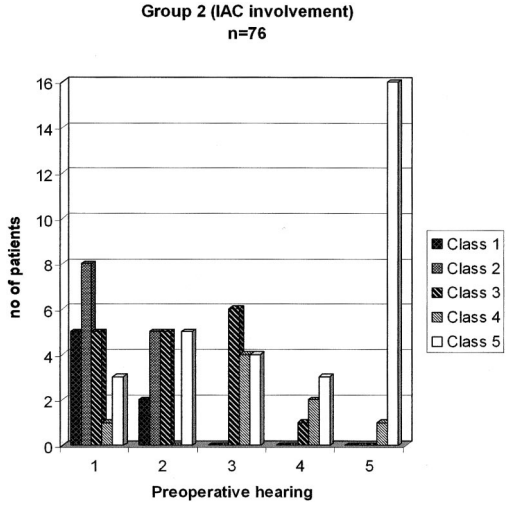

FIGURE 12. *Graph showing preoperative and postoperative auditory function in 76 CPA meningiomas involving the IAC (Group 2). The number of patients is presented according to their grade of hearing deficit before and after surgery. Of 22 patients, 5 (22.7%) maintained normal hearing after surgery, 2 patients improved from preoperative Class H2 hearing to normal hearing, 7 (41.2%) of 17 patients with preoperative Class 2 hearing retained hearing at least at the same level, and 6 (42.9%) of 14 patients maintained hearing at Class H3. One patient improved from preoperative Class 4 hearing to Class 3 hearing. Three (50%) of 6 patients retained at least the same hearing level at Class 4. The hearing of 1 patient recovered from preoperative deafness to Class 4 postoperatively. The other 16 patients remained deaf. Hearing function was graded according to the Hannover Audiological Classification.*

patients (6.8%) were already deaf on the affected side before surgery. Postoperative results are presented in *Figure 15*.

Comparison among groups showed that normal preoperative hearing was more common in Group 3 (49.2%) and Group 5 (47.7%) compared with Group 2 (28.9%) and Group 4 (28.2%). The difference between Group 3 versus Group 2 or 4 was statistically significant ($P = 0.0135$ and $P = 0.035$, respectively). Normal preoperative hearing was significantly more common in Group 5 compared with Group 2 ($P = 0.0387$) but not compared with Group 4 ($P = 0.0682$). The immediate postoperative results of auditory function in patients with preoperative normal hearing is best in Groups 3 and 5 (preservation of normal hearing in 81.3 and 81%, respectively), followed by Group 1 (preservation of normal hearing in 63.3%) and Group 4 (preservation of normal hearing in 54.5%). Preservation of preoperative normal hearing was less common in Group 2 (22.7%) (*Table 2*). The difference between Group 2 versus Groups 3, 5, and 1 was highly significant ($P < 0.0001$, $P = 0.0001$, and $P = 0.0016$, respectively).

Improvement of auditory function in the immediate postoperative period from a preoperative hearing deficit ranging from Class H2 to H5 was observed most commonly in Group 5, in 8 (34.8%) of 23 patients, followed by Group 4, in 7 (25%) of 28 patients, and Group 3, in 8 (24.2%) of 33 patients. Improvements were less common in Group 2 (4 [7.4%] of 54

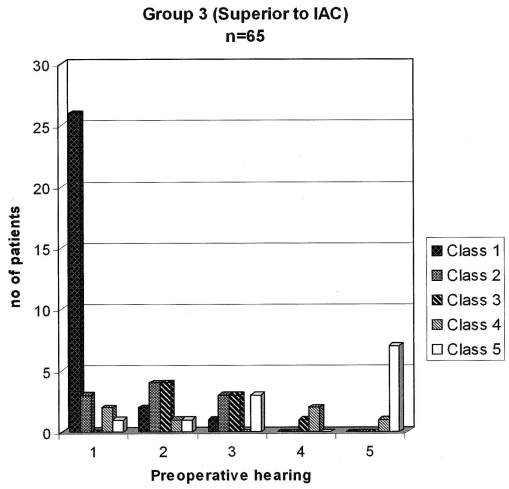

FIGURE 13. *Graph showing preoperative and postoperative auditory function in 65 CPA meningiomas lying superior to the IAC (Group 3). The number of patients is presented according to their grade of hearing deficit before and after surgery. Of 32 patients, 26 (81.3%) maintained normal hearing after surgery, 2 patients improved from Class H2, and 1 patient improved from Class H3 to normal hearing. Six (50%) of 12 patients retained hearing at least at the same preoperative level (Class H2 or better), 3 patients improved from preoperative Class H3 to Class H2 after surgery, and 7 (70%) of 10 patients retained hearing at the same preoperative level (Class H3) or improved. One patient showed improvement from Class H4 to Class H3. All 3 patients maintained hearing level at preoperative Class H4 or better. Among 8 patients presenting with functional deafness before surgery, 1 improved to Class H4 hearing, and the others remained deaf. Hearing function was graded according to the Hannover Audiological Classification.*

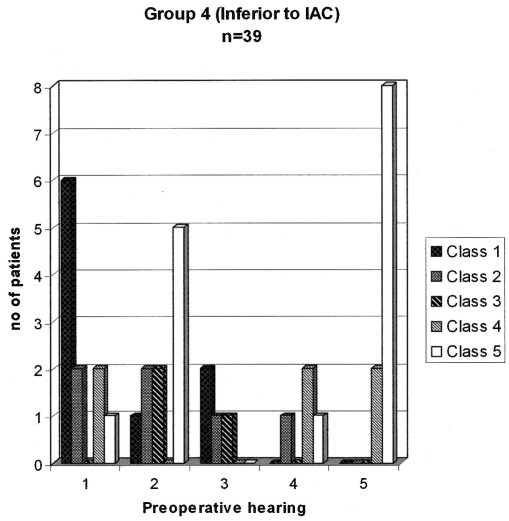

FIGURE 14. *Graph showing preoperative and postoperative auditory function in 39 CPA meningiomas lying inferior to the IAC (Group 4). The number of patients is presented according to their grade of hearing deficit before and after surgery. Six (54.5%) of 11 patients maintained normal hearing (Class H1) after surgery, and 1 patient improved from Class H2 and 2 patients from Class H3 to normal hearing. Three (30%) of 10 patients retained hearing at least at the same preoperative level (Class 2 or better). One patient improved from preoperative Class H3 to Class H2 after surgery. All 4 patients maintained hearing level at preoperative Class H3 or better. One patient showed improvement from preoperative Class H4 to Class H2. Three (75%) of 4 patients maintained hearing level at preoperative Class H4 or better postoperatively. Among 10 patients presenting with functional deafness before surgery, 2 improved to Class H4 hearing, and the others remained deaf. Hearing function was graded according to the Hannover Audiological Classification.*

patients) and Group 1 (7 [11.7%] of 60 patients). Recovery of auditory function from preoperative functional deafness (Class H5) in the immediate postoperative course was observed most commonly in Group 5 (2 [66.6%] of 3 patients), followed by Group 4 (2 [20%] of 10 patients) and Group 3 (1 [12.5%] of 8 patients) (*Table 2*). Recovery from preoperative deafness occurred in only 1 (5.9%) of 17 patients in Group 2.

The outcome of auditory function depending on the surgical approach did not reveal any significant difference. Of 17 patients (Group 1, 2, and 3 tumors) who were operated on via the combined supratentorial-infratentorial approach, 9 (52.9%) had normal preoperative hearing (Class H1). Five (55.6%) of these 9 patients had preservation of normal hearing function. Among 233 patients with Group 1 to 3 tumors who underwent surgery through the lateral suboccipital approach, 94 patients (40.34%) had normal preoperative hearing (Class H1). Of these 94 patients, 57 (60.6%) had preservation of normal hearing function after surgery. There was no statistically significant difference concerning outcome of hearing function between the two approaches ($P = 0.766$).

Tumor size as a possible relevant factor concerning outcome of postoperative hearing function was examined. There were 149 tumors (44.6%) with a diameter less than 3 cm; 67 patients (45%) among them had normal preoperative hearing function (Class H1). In 41 patients (61.2%), normal hearing function was preserved postoperatively. One hundred eighty-five patients (55.4%) had tumors larger than 3 cm. Among them, 68 patients (36.8%) had normal preoperative hearing function (Class H1). Of these, 44 (64.7%) had preservation of normal hearing after surgery. Statistical comparison did not reveal any significant difference concerning outcome of hearing function between the two groups ($P = 0.6727$).

The relationship between the extent of tumor resection and hearing function was investigated. Forty-eight tumors were subtotally resected. Among them, 11 patients (22.9%) had normal preoperative hearing function (Class H1). In 8 patients (72.7%), hearing was preserved on the same level after surgery. Total tumor resection was achieved in 286 patients. Normal preoperative hearing function was observed in 124 patients (43.9%). In 77 patients (62.1%), preservation of facial nerve function on the same level was possible. Statistical comparison did not show any significant difference concerning outcome of hearing function between the two groups ($P = 0.4841$).

Tumors with intrameatal involvement (Group 2 tumors) were analyzed separately. Among 76 tumors, 9 were subtotally removed. Among them, no patient presented with nor-

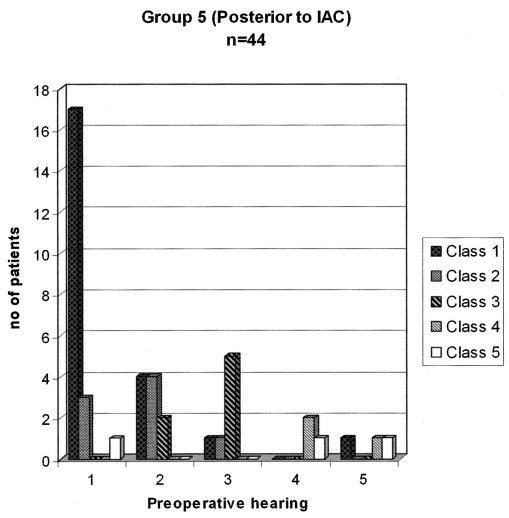

FIGURE 15. *Graph showing preoperative and postoperative auditory function in 44 CPA meningiomas lying posterior to the IAC (Group 5). The number of patients is presented according to their grade of hearing deficit before and after surgery. Seventeen (81%) of 21 patients maintained normal hearing after surgery, 4 patients improved from preoperative Class H2, and 1 patient improved from Class H3 to normal hearing. There was even 1 patient in whom hearing recovered dramatically from preoperative functional deafness to normal hearing after surgery. Eight (80%) of 10 patients retained hearing level at Class H2 or better after surgery. One patient improved from Class H3 to Class H2. All 7 patients presenting with Class H3 hearing retained hearing level at Class H3 or better after surgery. Two (66.6%) of 3 patients maintained hearing level at Class H4. One patient with preoperative functional deafness improved to Class H4 hearing after surgery. Altogether, 2 (66.6%) of 3 patients presenting with functional deafness showed postoperative improvement. Hearing function was graded according to the Hannover Audiological Classification.*

mal hearing function (Class H1). Sixty-seven patients underwent total resection; among them, 22 patients (32.8%) had normal hearing function (Class H1). Five patients (22.7%) had preservation of cochlear nerve function at the same level postoperatively.

Long-term Follow-up

The long-term follow-up of facial nerve function was available in 324 patients. Ten patients were lost during follow-up, among them 8 patients because of death as a result of other medical conditions. The mean clinical follow-up time was 62.3 months (range, 2–214 mo).

Of 13 patients with H-B Grade 3 immediately after surgery, 5 patients improved to H-B Grade 1 to 2 during follow-up. Five of 13 patients with H-B Grade 4 also improved to good facial nerve function (H-B Grade 1–2), and 3 patients improved to H-B Grade 3. One of 6 patients with postoperative H-B Grade 5 improved to good facial nerve function (H-B Grade 1–2), and 5 patients improved to H-B Grade 3. Of 18 patients with postoperative H-B Grade 6, 2 improved to H-B Grade 1 to 2, 10 patients showed improvement to H-B Grade 3, including 5 cases of facial nerve reconstruction, and 1 patient improved to H-B Grade 4. Altogether, 297 (88.9%) of 334 patients had good facial nerve function (H-B Grade 1–2) on long-term follow-up (*Fig. 16*).

Data concerning auditory function were available for 313 of 333 patients on long-term follow-up. Ten patients were lost to follow-up, among them 8 patients because of death as a result of other medical conditions. In 10 patients, an audiogram was not available during follow-up. Of 62 patients with postoperative Class H2 hearing, 36 patients improved to normal hearing (Class H1). Among 50 patients with postoperative Class H3 hearing, 20 patients improved to normal hearing and 6 patients to Class H2 hearing. Of 34 patients with postoperative hearing deficit of Class H4, 6 patients improved to normal hearing, and 9 improved to Class H3 hearing. Among 86 patients who had functional deafness postoperatively, 6 patients improved even to normal hearing, and 5 patients improved to Class H4 hearing (*Fig. 17*).

In summary, 169 (50.8%) of 333 patients had normal hearing (Class H1) on long-term follow-up; in 258 (90.8%) of 284 patients presenting with hearing function of class H1 to H4 preoperatively, hearing preservation (postoperative hearing function of Class H1–H4) was possible on long-term follow-up.

DISCUSSION

Only a few reports analyzed the outcome of facial nerve function and audiometric data after surgery of CPA meningiomas. The results were variable and were influenced in part by the different surgical approaches for removal of these tumors.

In recent microsurgical series, facial nerve function could be preserved in the majority of patients. Schaller et al. (29) reported on 6 of 10 patients with normal preoperative facial nerve function retaining H-B Grade 1 to 2 after surgery by use of the retrosigmoidal suboccipital approach. Voss et al. (37) reported about facial nerve dysfunction in 30% in their series of 40 patients with CPA meningiomas operated on via different approaches.

The presence of facial nerve paresis before surgery was considered to be a risk factor for pronounced postoperative facial weakness (29). In our series, patients presenting with H-B Grade 2 to 3 preoperatively showed worsening of facial nerve function in 28.9% on average in all tumor groups. In patients presenting with normal facial nerve function (H-B Grade 1), deterioration of facial nerve function was observed in only 18.3% (Group 1–5 on average). However, the presence of preoperative facial nerve paresis was different depending on the location and origin of tumors. Preoperative facial weakness was more common in tumors involving the IAC (Group 2) or in tumors located anterior to the IAC (Group 1) compared with tumors originating superior (Group 3) or posterior (Group 5) to the IAC. Also, improvement of preoperative facial nerve paresis after surgery was more commonly observed in Group 3 and Group 5 tumors compared with Group 1 and 2 tumors.

TABLE 2. Preservation rate of auditory function on the same level after surgery (including improvements)[a]

	Group 1	Group 2	Group 3	Group 4	Group 5
Class H1	31/49 (63.3%)	5/22 (22.7%)	26/32 (81.3%)	6/11 (54.5%)	17/21 (81%)
Class H2	12/17 (70.6%)	7/17 (41.2%)	6/12 (50%)	3/10 (30%)	8/10 (80%)
Class H3	13/19 (68.4%)	6/14 (42.9%)	7/10 (70%)	4/4 (100%)	7/7 (100%)
Class H4	7/13 (53.8%)	3/6 (50%)	3/3 (100%)	3/4 (75%)	2/3 (66.6%)
Class H5 (improvements)	1/11 (9%)	1/17 (5.9%)	1/8 (12.5%)	2/10 (20%)	2/3 (66.6%)

[a] Hearing function was graded according to the Hannover Audiological Classification (H).

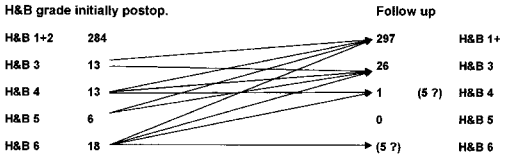

FIGURE 16. *Graph showing facial nerve function after long-term follow-up (mean, 62.3 mo). The number of patients is listed according to their grade of facial nerve function in the immediate postoperative (*postop.*) period (*left*) and after long-term follow-up (*right*). The long-term follow-up of facial nerve function was available in 324 patients. Ten patients were lost during follow-up (indicated with ?), among them 8 patients because of death as a result of other medical conditions.* H&B, *H-B grade.*

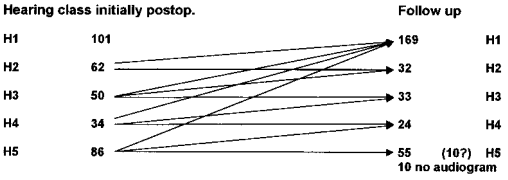

FIGURE 17. *Graph showing auditory function after long-term follow-up (mean, 62.3 mo). Data concerning auditory function was available from 313 patients on long-term follow-up. Ten patients were lost to follow-up, among them 8 patients because of death as a result of other medical conditions. In 10 patients, an audiogram was not available during follow-up (indicated with ?). Hearing function was graded according to the Hannover Audiological Classification (*H*).* Postop., *postoperative.*

As mentioned previously, tumor location seems to affect the clinical outcome in surgery of CPA meningiomas (2, 25, 30, 37). Schaller et al. (30) reported that postoperative outcome of facial nerve function was substantially worse in premeatal than in retromeatal tumors. Voss et al. (37) reported in their series that facial nerve paresis occurred postoperatively in 60% of tumors arising anterior to the IAC, in 50% of tumors arising inferior to the IAC, and in less than 15% of tumors arising either posteriorly or superiorly. Batra et al. (2) emphasized that all 10 patients with retromeatal tumors had H-B Grade 1 facial nerve function preoperatively and that all of these patients retained Grade 1 function after surgery. Seven patients with premeatal tumors had Grade 1 function preoperatively, but only 1 patient maintained Grade 1 function after surgery in their series. Consistent with these previous findings, we have observed substantial differences of facial nerve outcome depending on the tumor location. Tumor size did not have any significant influence on facial nerve outcome. Normal preoperative facial nerve function could be preserved in the majority of patients, ranging from 76.3% in Group 1 tumors (lying anterior to the IAC) to 90% in Group 5 tumors (lying posterior to the IAC). In tumors involving the IAC (Group 2), normal facial nerve function could be maintained in 79% of patients. Tumors originating superior and inferior to the IAC (Group 3 and 4) also had a better chance of preservation of normal facial nerve function, at 84.5 and 87%, respectively. The more intimate relation of intrameatal tumors with the facial nerve may account for the slightly lower likelihood of preservation of normal facial nerve function postoperatively. In tumors located anterior to the IAC, with frequent posterior displacement of the facial nerve, the outcome of facial nerve function is worse because of the increased risk of damage to this structure during surgery through the lateral suboccipital approach, because it represents a continuous obstacle during tumor removal. However, compared with the more extensive combined infratentorial-supratentorial approach, in which an additional presigmoidal avenue is provided for tumor resection, the overall outcome of facial nerve function was not significantly different.

The clinical course on long-term follow-up showed further improvement of postoperative facial paresis in some patients, finally resulting in 88.9% of all patients with good facial nerve function (H-B Grade 1–2), and therefore, it is mandatory to attempt facial nerve preservation in every case of CPA meningioma.

There are only a few previous reports about postoperative audiometric data in the literature. The surgical management of CPA meningiomas with regard to attempts at hearing preservation also differed depending on the preference of different approaches used for tumor removal. Grey et al. (9) attempted hearing preservation through the retrosigmoidal approach in 16 patients. Serviceable or better hearing was preserved in 8 (73%) of 11 patients in whom it was present before surgery. Nassif et al. (20) attempted hearing preservation in 16 of 56 patients with CPA meningiomas, and hearing level was preserved near the preoperative level in 75% of patients postoperatively. Schaller et al. (30) reported that auditory function could be preserved in 11 (65%) of 17 retromeatal tumors. These studies showed that in the

majority of patients, hearing preservation was possible; however, it has to be pointed out that this was attempted in only selected patients in whom preoperative hearing was either normal or only mildly impaired (10, 20). In other patients, hearing-destructive approaches were often considered for surgery. Schaller et al. (30) attempted to preserve hearing only in retromeatal tumors, and it was considered that it is not possible to preserve hearing in premeatal tumors, which all presented with nonserviceable hearing preoperatively.

Tumor location strongly affected the outcome of auditory function after retrosigmoidal tumor removal in our series. We attempted to preserve the cochlear nerve anatomically and functionally independent of tumor location or preoperative hearing level by use of the lateral suboccipital retrosigmoidal approach in the majority of patients. Postoperative results of auditory function in patients with preoperative normal hearing (Class H1) was best in Groups 3 and 5 (preservation of normal hearing in 81.3 and 81%, respectively), followed by Group 1 (preservation of normal hearing in 63.3%) and Group 4 (preservation of normal hearing in 54.5%). Preservation of preoperative normal hearing was less common in Group 2 (22.7%). Although patients with tumors with premeatal location (Group 1) or intrameatal involvement (Group 2) more commonly present with hearing deficits preoperatively (Class H2–H4), preservation of hearing at least at the same level or improved hearing could be achieved in 55.8% (average of both groups). In tumors involving the IAC, the cochlear and facial nerves have an intimate relation to the tumor, especially during their intrameatal course. In this subgroup of meningioma, these nerves are also more commonly surrounded by tumor mass, requiring more frequent preparation at the nerve-tumor border. This may be the reason for the less likely preservation of normal hearing in this subtype of tumor.

Although this was not statistically significant, patients harboring tumors that were located inferior to the IAC (Group 4) had a less favorable preservation rate of normal hearing compared with other tumor subgroups (Group 2 excluded). It is unclear whether this was because of the more frequently encountered superior displacement of the cochlear nerve in this type of tumor. It is also worth mentioning that patients with Group 4 tumors less frequently presented with normal preoperative hearing (Class H1, only 28.2%), similar to patients with Group 2 tumors. These findings would favor a hypothesis that the cochlear nerve is generally more impaired when displaced superiorly and even more susceptible to surgical manipulation during tumor removal in this unusual position.

In retromeatal tumors (Group 5), the rate of hearing preservation at least at the same level or improvement was highest, at 85% (Class H2–H4 preoperatively) compared with tumors with other locations. In seven patients, even recovery from preoperative functional deafness occurred. One patient each recovered from deafness in Groups 1 to 3 and two patients each in Groups 4 and 5. In one deaf patient with a retromeatal tumor (Group 5), even dramatic hearing recovery to normal hearing was observed. Few case reports have previously demonstrated that hearing restoration can occur with CPA meningiomas, even in the face of profound preoperative deficit (4, 7, 18, 35). In our view, these cases show that it is worth attempting hearing preservation in as many patients as possible, even in the case of bad or no clinical preoperative hearing.

The rate of hearing preservation in surgery for CPA meningiomas is different compared with vestibular schwannoma surgery (16, 27). The present analysis of 2000 vestibular schwannomas operated on in our department showed that the rate of hearing preservation depended on the preoperative hearing quality and the tumor size. Good chances of hearing preservation were encountered in patients with normal or good preoperative hearing, with 70% in intrameatal tumors (T1), 65% in tumors with intrameatal-extrameatal extension (T2), 56% in medium-sized tumors (T3), and 25% in tumors with brainstem compression or even dislocation (T4). In an earlier review of 10 surgical series (6), hearing preservation rate was found to be 33% for these tumors.

In our series of CPA meningiomas, hearing preservation among patients presenting with functional hearing (Class H1–H4) was achieved in 90.8%, including those patients with improvement on long-term follow-up. The results were dependent on tumor extension and location but not on the tumor size. Reviewing these data, the overall possibility of hearing preservation is superior for CPA meningioma compared with vestibular schwannomas. The observed difference in results may be because of the more intimate involvement of vestibular schwannomas with the cochlear nerve or its blood supply. Direct trauma to the cochlear nerve or deterioration of the blood supply during manipulation for tumor removal in vestibular schwannomas may result in lower success rates in hearing preservation. Although the pathophysiological changes at the tumor-nerve border in schwannomas and meningiomas and the differences in either group are not well understood, every attempt has to be made to preserve hearing in as many patients as possible. Especially in CPA meningiomas, our and previous results show that restoration of auditory function is possible even in patients with preoperative profound hearing deficit or functional deafness. Hearing preservation should not be limited to patients with retromeatal meningiomas (Group 5 in our series) with good or serviceable preoperative hearing. These tumors also had the best success rate in our series, but hearing conservation or improvement is also possible in tumors with more challenging locations.

The presented data with continuous improvement of functional outcome along with a high rate of surgical radicality were achieved thanks to the support of intraoperative neurophysiological monitoring. Neurophysiological monitoring experience has been gathered over a period of 15 years in a large patient entity with various posterior fossa tumors, such as vestibular schwannomas (acoustic neuromas), epidermoids, meningiomas, vascular compression syndromes, and other pathological conditions. The significance of neuromonitoring has been demonstrated in a recent study on large vestibular schwannomas with brainstem involvement in which not only the rates of functional nerve preservation but also the quality of preserved hearing were improved (16). Multimodality functional control during each microsurgical step has increased knowledge about ongoing changes caused by microsurgical

maneuvers as well as their safety. Somatosensory evoked potentials are used to increase safety during patient positioning and at tumor resection in adherent processes at the brainstem (*en plaque* meningiomas). By recording of the electromyography of motor cranial nerves, early nerve identification and delicate handling of the nerve during tumor resection are enabled. The rate of anatomic facial nerve preservation increased by this, whereas surgical radicality increased as well. Intraoperative monitoring of auditory brainstem responses intensified the surgeons' awareness as well as the rate of functional preservation of the cochlear nerve. In a current study, the influence of monitoring on the surgical procedure and the outcome with and without monitoring in CPA tumors are being investigated. At present, it may be summarized that neurophysiological monitoring, after the initial period of adaptation, increases surgical radicality, the quality of functional outcome, and the speed of surgery.

CONCLUSION

The outcome of facial and cochlear nerve function is different in CPA meningiomas depending on the topographic classification of these tumors. Better results are achieved with tumors located posterior (Group 5) or superior (Group 3) to the IAC compared with tumors with a premeatal location (Group 1) or intrameatal involvement (Group 2). Hearing preservation or even improvement is also possible in less favorable tumors with premeatal or intrameatal extension by use of the lateral suboccipital retrosigmoidal approach, and therefore, we do not recommend the use of hearing-destructive cranial base approaches in any case of CPA meningioma. Preservation of the cochlear nerve should be attempted in every patient, keeping in mind that recovery of hearing was also observed in preoperatively deaf patients.

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COMMENTS

Professor Samii continues to set the standard for posterior fossa surgery for benign tumors. In this instance, Nakamura et al. discuss cerebellopontine angle meningiomas and the preservation of hearing and facial nerve function despite technically difficult surgery. They have learned that patients with tumors that are superior to the porus or posterior to it fare better clinically after surgery than those with tumors that are intracanalicular or anterior to the acoustic canal. The rate of complications in the series seems remarkably low despite surgery for lesions that present a challenge for all neurosurgeons.

The detailed article provides specific information that will be used as reference material for future authors attempting to improve on this remarkable series. Someday another publication from another group will compare their data to the Hannover experience. Progress probably will come, but it will not be spectacular from this point onward.

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Nakamura et al. provide an excellent review of the extensive series of cerebellopontine angle meningiomas operated on by Professor Samii and the results. The term *cerebellopontine angle meningioma*, as used by the authors, could be somewhat confusing. In general, when the tumor arises from the petrous ridge medial to the internal auditory canal, it usually involves the clival area as well, and I classify such tumors as *petroclival meningioma*. I reserve the term *cerebellopontine angle meningioma* for tumors arising from the posterior petrous ridge, from the internal auditory canal itself, or from the petrous ridge superior to the internal auditory canal with significant extension into the cerebellopontine angle. It is difficult to determine the type of tumors the authors discuss without seeing the patients' magnetic resonance imaging scans. This is of more than semantic interest when one attempts to compare the results of one series or one operative approach with another.

Another issue that may be raised is how many of the patients were candidates for radiosurgery and the results in these patients. This is an important question in considering the treatment options for such patients in the future.

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Nakamura et al. present a large series of 347 cerebellopontine angle meningiomas operated on at a single institution during a 24-year period. Their overall results are impressive for achieving gross total resection in 86% of cases, preservation of preoperative facial nerve function in 80% of cases, and preservation of preoperative functional hearing in 91% of cases. Tumor size did not influence the rate of functional facial nerve outcome or hearing preservation. Hearing preservation was achievable even in tumors with intrameatal extension, emphasizing the importance of a hearing-preserving approach in the vast majority of patients with cerebellopontine angle meningiomas

The authors expand on the pre- and retromeatal classification of Schaller el al. (2) by considering tumor origins anterior to (Group 1), superior to (Group 3), interior to (Group 4), posterior to (Group 5), or within (Group 2) the internal auditory canal. In concordance with Schaller et al. (2), tumors arising from retromeatal (Group 5) locations experience significantly better postoperative facial nerve outcomes than those originating from premeatal (Group 1) locations (90% versus 76%; $P = 0.04$). Likewise, hearing preservation is more likely for retromeatal tumors than premeatal tumors. These results reflect the fact that tumors arising anterior to the internal auditory canal tend to dissection via the retrosigmoid approach. Because of this, many neurosurgeons prefer the presigmoid approach for Group 1 tumors (otherwise known as petroclival meningiomas), as it places the VIIth and VIIIth nerve complex in a more caudal location within the operative corridor and allows more direct access to the tumor capsule (1). The authors documented no significant difference in outcomes between the retrosigmoid and presigmoid approach, but it is notable that 95% of operations were conducted via the retrosigmoid approach.

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1. Abdel Aziz KM, Sanan A, van Loveren HR, Tew JM, Keller JT, Pensak ML: Petroclival meningiomas: Predictive parameters for transpetrosal approaches. **Neurosurgery** 47:139–152, 2000.
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Nakamura et al. present a study analyzing postoperative facial and cochlear nerve function after surgery of meningiomas of the cerebellopontine angle. The vast experience of the senior author and surgeon, Professor Samii, allows the presentation of the largest reported series of 421 cerebellopontine angle meningiomas, of which data for 347 patients were available for complete analysis.

The authors demonstrated that the surgical outcome is independent of the tumor size but significant depending on the topography of tumor location in relation to the inner acoustic canal and the nerve structure. This message is not new. As this large series allows us to categorize the tumor origin into five groups and to provide analysis regarding facial and acoustic nerve damage, it has been shown clearly when the tumor involves the internal auditory canal or is anteriorly localized, patients more often have facial nerve palsy and hearing deficit than do those with posterior localization. The involvement of nerve structures within the tumor or its posterior displacement renders the patient prone to nerve injury. This detailed information allows the surgeon to conduct a more precise preoperative assessment of probable nerve injury during the surgical approach. Therefore, patients can be given more accurate guidance and expectations for surgery.

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