“En-Bloc” Removal of Small- to Medium-Sized Acoustic Neuromas With Retrosigmoid-Transmeatal Approach

ABSTRACT—Surgery of acoustic neuroma (AN) has significantly refined over the past years due to a series of advances in diagnostics and surgical technique. Electrophysiologic investigation performed during surgery has greatly contributed to this progress, increasing the surgeon's understanding of the mechanism of damage and suggesting various changes in his or her surgical strategy.

In this context, the advantages of the retrosigmoid “en-bloc” removal of small to medium size ANs have been examined in the present study. At the ENT Department of the University of Verona, 103 subjects with AN were operated on, from January 1990 to December 1995, with a retrosigmoid-transmeatal approach. Eighteen subjects (17.4%) presented a pure intracanalicular (IC) tumor and 85 (82.6%) had both IC and extracanalicular (EC) involvement. All the IC tumors ($n = 18$) and 70 of the IC-EC neuromas with an EC size less than 25 mm are reported in this paper for a total of 88 patients. The first 48 patients were operated on via the classic procedures described in the literature, characterized by removal of the tumor after “debulking” and limited exposure of the internal auditory canal (IAC). The following 40 subjects were operated on according to the technique of “en-bloc” removal of the tumor and wide exposure of the IAC.

In the “en-bloc” group, the tumor was first detached from the cerebellar flocculus and the pons, when necessary. The tumor was not debulked to preserve the anatomic relationship with the nerves and to facilitate identification, cleavage, and dissection of the tumor from the neural structures. Thereafter, the posterior wall of the IAC was drilled out and opened in a circumferential range from 180 to 270°. The IAC dura was subsequently opened, and the distal end of the AN along with the vestibular nerves were identified. The vestibular nerves were sectioned in the distal portion of the IAC and dissected with the tumor from the underlying facial and cochlear nerves. Dissection continued medially to the IAC porus. The AN was progressively dissected from the cochlear and facial nerves in the cerebellopontine angle (CPA) with multiple direction maneuvers, as required by the characteristics and degree of adherence to the neural structures.

The anatomic and functional results obtained with this new procedure (“en-bloc” removal) were compared with the classic “debulking” technique. The statistical analysis shows an improvement in postoperative outcome for both auditory and facial nerve function. The “en-bloc” removal procedure along with the wide exposure of the content of the IAC and electrophysiologic monitoring of the seventh and eighth cranial nerves are, in our experience, the recommended strategies for improving outcomes in small to medium size ANs.

Advances in neuro-otologic diagnosis (eg, magnetic resonance imaging (MRI) with gadolinium enhancement and auditory evoked potentials), refinements in surgical technique, and improved intraoperative facilities (eg, intraoperative monitoring) have made acoustic neuroma (AN) surgery a safe procedure in recent years. The prevalence of postoperative severe complications and recurrence rates has, in fact, undergone a dramatic and progressive reduction, whereas preservation of facial nerve (FN) function and useful hearing has improved.

The possibility of preserving hearing particularly influences the decision regarding the surgical approach, with preferences for conservative surgical routes, ie, retrosigmoid and middle fossa approaches.

We prefer the retrosigmoid approach due to its versatility, safety, and the possibility it offers to perform a direct recording of cranial nerve action potentials. The classic suboccipital neurotologic approach has been modified over the past decades from a wide exposure of the posterior fossa¹ to the more conservative retrosigmoid craniotomy,² and, finally, to the modern retrosigmoid-transmeatal (RS-TM) approach.³⁻⁷

The present paper describes our current technique used to remove AN via the RS-TM approach which aims to preserve FN and, whenever possible, auditory functions. The characterizing requisites of this technique are the extracapsular, extra-arachnoidal ("en-bloc") removal of the tumor, the wide opening of the internal auditory canal (IAC), and the direct recording of cochlear and facial nerve action potentials.

MATERIALS AND METHODS

From January 1990 to December 1995, 103 patients with AN were operated on in our department by the first author (V.C.) via a retrosigmoid-transmeatal approach. Eighteen subjects (17.4%) presented a pure intracanalicular (IC) development and 85 (82.6%) both an IC and extracanalicular (EC) involvement. All the IC tumors and 70 of the IC-EC neuromas with an EC development less than 25 mm are represented in the study group. The first 48 patients were operated on via the

Table 2. Preoperative Hearing Level (AAO, 1995)

	<i>Debulking group</i> (n = 48)	<i>En-bloc Group</i> (n = 40)
Class A	15	12
Class B	18	17
Class C	7	6
Class D	8	5

classic procedures described in the literature, characterized by removal of the tumor after "debulking."³⁻⁷ The following 40 subjects were operated on according to the technique of the extracapsular ("en-bloc") removal. Table 1 shows the characteristics of both groups.

Most patients presented normal facial function preoperatively (grade I according to House and Brackmann⁸). In five subjects of the "debulking" group (10.4%) and four (10%) of the en-bloc group, the facial function was of grade II.

Table 2 shows the distribution of auditory function in both groups of patients, as evaluated according to the guidelines of the AAO Committee on Hearing and Equilibrium.⁹ Patients in classes A and B, 33 in the "debulking" group, and 29 in the en-bloc group, were admitted to the hearing preservation program.

Surgical Technique

A modified supine position is utilized. It is preferred to the sitting position, as it is more comfortable for the surgeon, more physiologic for the patient, allows optimal tumor exposure, prevents air embolism, and prevents the nerves and vascular structures from drying.¹⁰

The patient lies with the body slightly rotated away from the surgeon with the aid of a wedge-shaped sponge. The head is extended, rotated contralaterally to the ear operated on and parallel to the floor to furnish the surgeon a direct view of the retrosigmoid region. The head is fixed with adhesive tape to the operating

Table 1. General Characteristics of the Two Investigated Groups

	<i>Males/ Females</i>	<i>Age</i>	<i>AN Diameter</i>	
			<i>IC</i>	<i>EC</i>
Debulking group (n = 48)	1.23	mean range 53.3 (18-70)	mean range 6 (2-9)	mean range 17 (7-25)
En-bloc group (n = 40)	1.13	52.5 (21-68)	6.5 (2-10)	15 (5-25)
t-test	NS	NS	NS	NS

table. During surgery, the point of view of the surgeon is modified when necessary by rotating the table along its longitudinal and transverse axes.

The skin incision is straight, approximately 6 to 8 cm long and follows the hairline retroauricularly. The suboccipital muscles are partially detached from the occipital bone using subperiosteal dissection. A mastoid emissary vein is frequently bleeding in this stage and needs to be sealed with bone wax.

A roughly 4-cm diameter retrosigmoid craniotomy is performed. Its anterior and rostral limits are represented by the sigmoid and transverse sinuses, respectively. The bony area to be removed is first outlined by cutting burs. Thereafter, the sigmoid sinus is identified. It lies just anterior to the back side of the body of the mastoid bone, and its axis can be determined by connecting the asterion to the mastoid tip. Identification of the sinus is facilitated by following the emissary vein.

Exposure of the sigmoid sinus may result in the opening of some mastoid air cells which are obliterated with bone wax. After skeletonization of the sigmoid sinus, the transverse sinus is followed for 2 to 3 cm. The rostral and anteroinferior angle of the craniotomy is prepared by further skeletonizing the sigmoid sinus using cutting and diamond burs. This maneuver is of paramount importance for the optimal exposition of the CPA.

The medial edges of both sinuses are completely exposed to allow depression of the nearby dura. The residual bone flap is preserved to partially obliterate the craniotomy after surgery. Mannitol (250 mL at 18%) is administered during the craniotomy to facilitate cerebellar retraction. Under the microscope, the dura is incised along a convexity toward the sigmoid sinus. The incision is therefore extended by performing two small lateral incisions towards the sigmoid sinus. Sutures are placed to hold the dural flaps. A self-retaining Leila retractor is used to elevate gently the cerebellum in a caudal to cranial direction. Sharp dissection of the arachnoid facilitates access to these structures.

Cerebrospinal fluid (CSF) egression, in combination with mannitol allows CPA exposure with minimal cerebellar retraction. During this maneuver, the cerebellum is protected from the blade of retractor by a latex sheath. The mixed nerves are first visualized, then the tumor and/or the eighth nerve.

Exerting further depression on the cerebellum, the entire area from the brainstem to the posterior wall of the petrous bone and to the tentorium is exposed. The trigeminal nerve is visualized cranially in this stage.

Extracapsular (En-Bloc) Tumor Removal

Main vessels are gently detached from the tumor capsule. Small vessels adherent to the capsule are coagulated with bipolar coagulation.

When the AN reaches the pons or the cerebellum, it is gently detached from its adherences. In medium-sized tumors the cochleovestibular nerve is usually visualized with moderate dissection. Landmarks are followed to identify the facial, cochlear, and vestibular nerves in the medial side of the tumor. These nerves are identified at the lateral end of the pontomedullary sulcus, just rostral to the glossopharyngeal nerve, just anterior-superior to the foramen of Luschka, flocculus, and choroid plexus protruding from the foramen of Luschka.¹¹ At this point a monopolar electrode for recording cochlear and facial nerve action potentials is located at the root entry zone of these nerves. The procedure is extensively described elsewhere.¹²⁻¹⁵

Vestibular, cochlear, and facial nerves are identified from their root entry zone to the tumor. Thereafter, the attention of the surgeon is directed to drilling of the IAC while the electrophysiologic testing of the seventh and eighth cranial nerves is ongoing. The dura over the IAC is coagulated, and two dural flaps are prepared and reflected laterally. The posterior wall of the IAC is drilled out 180° to 270° of its circumference by using high-speed cutting and diamond burs with suction and irrigation for cooling. When hearing is lost, lateral extent of drilling to the fundus is accomplished.

The relationship between semicircular canals, vestibule, IAC fundus, and lateral tumor extension, are evaluated preoperatively by MR and CT imaging and used as landmarks to determine lateral extension of bone removal. In particular, relationship between IAC and labyrinth is evaluated at the CT scan. Drilling of IAC wall must be medial to the imaginary line connecting the posterior edge of the sigmoid sinus with the IAC fundus (Tatagiba's line).¹⁶ When the AN reaches the IAC fundus, careful attention and close observation are necessary to recognize a blue line as the labyrinth is approached.

During IAC drilling, the CPA is filled with spongoston to prevent bone dust contamination of subarachnoid spaces and aseptic meningitis. If the jugular bulb is bulging cranially into the meatus, it is gently compressed with surgical and bone wax.

After removing the posterior IAC wall, the dura that lines the meatus is incised and the IC portion of the tumor is visualized. The vestibular nerves are cut and retracted medially along with the distal portion of the tumor (Fig. 1).

A cleavage plane between the tumor posteriorly and the cochlear and facial nerves anteriorly is easily established at this level (Fig. 2). However, if the anatomy is distorted, bipolar recording of cochlear nerve action potentials (CNAPs)¹⁷⁻¹⁹ and electrical stimulation of the FN facilitates anatomic identification.

The facial and cochlear nerves are adherent in the canal, and any attempt at separation would compromise hearing.⁷ Blunt dissection following the cleavage plane continues from lateral to medial and from caudal to cra-

Figure 1. En-bloc removal of a 15-mm left AN. Retraction of the distal portion of the tumor in the IAC.

Figure 2. Tumor dissection from the facial and cochlear nerves up the IAC porus.

nial up to the IAC porus. Abrupt and exaggerated maneuvers are avoided in this very critical area to prevent possible stretching of the facial and cochlear nerves. If the tumor is adherent to the nerves, sharp dissection with microscissor may be necessary. The use of bipolar cautery is absolutely avoided and bleeding is controlled with continuous water irrigation.

Following tumor dissection up to the IAC porus, the attention is moved to the intracisternal portion of the tumor. After clear identification of the seventh and eighth cranial nerves at the brainstem exit zone, a proximal vestibular neurotomy is performed. The cleavage plane between the cochlear and the vestibular nerves is first identified by inspection and confirmed by means of electrophysiologic bipolar recording.¹⁷⁻¹⁹ The proximal end of the vestibular nerve, close to the brainstem, is cut and separated from the cochlear nerve in a medial to lateral fashion.

The extrameatal portion of the tumor is dissected in medial-to-lateral and inferior-to-superior directions, taking care not to damage the cochlear and facial nerves and the blood supply to the nerves and cochlea. To this end, the direction of the surgical maneuvers is changed frequently. When necessary, gentle low-intensity bipolar cauterization is always performed along with irrigation with saline solution.

The last part of dissection at the IAC porus is the most critical stage for facial and cochlear nerves. These nerves may be compressed against the IAC porus, displaced, flattened, and the fibers splayed out. Gentle dissection, frequent irrigation, and intraoperative monitoring of facial and cochlear nerves are of paramount importance at this stage.

The tumor is thus freed from these nerves and extracted en-bloc (Fig. 3). The IAC is carefully inspected by rigid fiberoptic endoscopes of varying view angles to exclude residual tumor in the IAC fundus.

The air cells of the posterior IAC wall are closed with bone wax and with homologous fascia and fibrine

glue. The CPA is copiously irrigated to remove debris and blood, and the retractor is removed.

The dura underlying the craniotomy is sutured watertight with interrupted sutures and reinforced with muscle plugs and fibrine glue. The osseous bone flap is positioned over the dura, and the wound is closed in layers.

Intracapsular (Debulking) Tumor Removal

The technique of tumor removal after debulking procedures has been extensively described in the literature.^{4-7,12} and here will be only briefly outlined. Most of the steps are similar to those performed during the en-bloc removal, but the tumor capsule is opened after coagulating small vessels, and the intracapsular content removed by using cup forceps. After debulking, the residual tumor capsule is detached from vascular and neural structures in a medial-to-lateral fashion. Bipolar coagulation is performed to control bleeding. Repeated sequences of debulking, tumor elevation, and dissection are performed.

Figure 3. AN removed en-bloc.

After initial debulking in the CPA, the sequence of removal may vary according to the anatomic situation. The tumor may be completely removed in the CPA, and thereafter the IAC portion is approached. More frequently, the EC tumor is debulked but not completely removed. Thereafter, the IAC is opened and the AN removed with a combined approach from the IAC and the APC.

When the IC extension is limited to a few millimeters, the IC portion of the tumor is removed en-bloc from the canal. Otherwise, debulking is also first performed in the IC portion in a medial-to-lateral fashion until the lateral end of the AN is reached.

Intraoperative Monitoring

Intraoperative monitoring of auditory (ABR, mono- and bipolar recording of CNAPs) and facial (EMG, FNAPs) functions are systematically performed during surgery with the purposes of identifying the nerves anatomically and detecting early functional damage. Auditory monitoring utilizes a monopolar recording electrode placed on the eighth nerve.¹² The electrode is located on the proximal portion of the eighth nerve or, when large tumors made placement on the nerve difficult, close to the cochlear nucleus area. The electrode is referenced to a subdermal platinum electrode (type E-2, Grass Instrument Company, Quincy MA), with a subdermal electrode placed on the sternum which serves as a ground.

The ear undergoing the operation is stimulated by rarefaction click stimuli at 31/second, generated by applying 100-microsecond rectangular electric pulses to walkman-type earphones.

Bipolar direct recording of CNAPs is utilized for identification of cochlear nerve fibers during surgery.¹⁷⁻¹⁹ Two silver electrodes insulated with Teflon® up to the exposed ends are utilized for bipolar recording of CNAPs. The electrodes are twisted together, inserted in a small polyethylene tube, and fixed to a hand-held sharp instrument with adhesive tape to permit accurate and rapid placement on the eighth nerve. The distance between the two electrode tips is approximately 1 mm. The silver wires are flexible and maintain their position whenever it proves necessary to bend them to probe blurred structures. The intensity of clicks administered to AN subjects ranges initially from 10 to 40 dBSL (re: psychoacoustic threshold). Prior to removing the tumor, the highest intensity of stimulation (usually 40 dBSL) is utilized for probing the tumor, the aim being to detect the proximity of the CN. When the response is absent at the bipolar recording, removal of the tumor begins. When a response is present or a nerve-like structure is visualized, stimulus intensity is decreased, usually to 15 to 25 dBSL. In this case, the nerve is repeatedly probed during tumor removal at the lowest intensity, which yields a reliable response.

Facial nerve monitoring is performed with the traditional electromyographic technique and with a personal method of direct recording of facial nerve antidromic potentials (FNAPs).^{13,14} A pair of platinum needle electrodes (types E2, Grass Instruments) are used to stimulate the marginal branch of the FN ipsilateral to the side operated on. Electrodes are placed 1 cm apart so that the imaginary line between them is perpendicular to the long axis of the nerve. Biphasic electric pulses of 50 microseconds duration are delivered seven times per second at an intensity ranging from 2 to 6 mA. Potentials are recorded using a teflon-insulated silver wire monopolar electrode. Fisher's exact test was used for statistical analysis of the results.

RESULTS

Facial nerve was anatomically preserved in all subjects of the en-bloc group and in 43 subjects (89%) of the debulking group ($p = 0.04$). Tables 3 and 4 show the postoperative facial function according to the House and Brackmann scale at discharge and after 1 year in both groups of patients.

At discharge, a good facial function (grades I and II) was achieved in 60.4% of patients of the debulking group and in 82.5% of the en-bloc group. The difference was significant ($p = 0.02$) for the Fisher's exact test (Table 3).

A 1-year follow-up was available in all 48 subjects of the traditional AN removal and in 31 subjects of the en-bloc removal group (Table 4).

FN function improved at 1 year compared to discharge in both groups. The percentage of subjects with good facial function (grades I and II) was 68.6% with the traditional debulking technique and 90.3% with the en-bloc technique. The difference was statistically significant ($p = 0.03$) using the Fisher's test.

Hearing preservation was attempted in 33 patients of the debulking group and in 29 of the en-bloc group. In 22 patients in the debulking group (66.7%) and in 27 subjects in the en-bloc group (93.1%), the cochlear nerve was anatomically preserved ($p = 0.01$).

Table 3. FN Function at Discharge

FN Grading	Debulking Group (n = 48)		En-bloc Group (n = 40)	
	N	(%)	N	(%)
I	17	(35.4)	20	(50.0)
II	12	(25.0)	13	(32.5)
III	7	(14.5)	4	(10.0)
IV	6	(12.5)	1	(2.5)
V	3	(6.3)	1	(2.5)
VI	3	(6.3)	1	(2.1)

Fisher's exact test (grades I-II vs III-VI): $p = 0.02$

Table 4. FN Function at 1 Year

FN Grading	Debulking group (n = 48)		En-bloc group (n = 31)	
	N	(%)	N	(%)
I	19	(39.5)	19	(61.2)
II	14	(29.1)	9	(29.1)
III	10	(20.8)	2	(6.5)
IV	2	(4.2)	1	(3.2)
V	1	(2.1)	—	
VI	1	(2.1)	—	

Fisher's exact test (grades I-II vs III-VI): $p = 0.03$

Classification of auditory results was performed according to the guidelines of the Committee of Hearing and Equilibrium of the AAO.⁹ Auditory results at discharge and at 1 year are reported in Tables 5 and 6. En-bloc removal technique allowed better auditory results at discharge, compared with the traditional technique (Table 5). Hearing preservation (classes A to C) was obtained in 48.4% of patients in the traditional removal group and in 72.4% of the en-bloc group. The difference was statistically significant ($p = 0.04$) for the Fisher's test.

At 1-year follow-up was available in all 33 subjects operated on by the "intracapsular debulking" tumor resection and in 24 of the "extracapsular en-bloc" group. Postoperative hearing preservation (classes A and C) was achieved in 48.1% of patients in the debulking group and in 75% in the en-bloc group. The difference was statistically significant ($p = 0.03$).

Postoperative complications are reported in Table 7. No significant differences between groups was observed in the prevalence of complications.

DISCUSSION

A number of surgical approaches to the posterior fossa and the IAC are available today for removing an AN, ie, translabyrinthine, transcochlear, middle fossa,

retrolabyrinthine, retrosigmoid. Choice of the approach depends on a number of factors, such as hearing level, size of the tumor, and, last but not least, the surgeon's experience and preference.

Growing interest in functional preservation of cranial nerves has focused surgeons' attention on the retrosigmoid and middle fossa routes. We prefer the retrosigmoid-transmeatal approach in any AN because in our hands it offers a series of advantages such as adequate control of bleeding, dissection of the entire tumor under direct view, easy identification of the facial nerve at its root entry zone and at the distal end in the IAC.^{4-7,12}

A particular feature of this approach is the unique possibility of performing real-time intraoperative monitoring by means of direct recording of cochlear nerve and facial action potentials (CNAPs and FNAPs). Instantaneous information on the function of the cochlea, and the cochlear and facial nerves are obtained with these techniques, and insights in the mechanisms of hearing and facial nerve impairment are therefore available during surgery.^{12-15,20} Information yielded by intraoperative monitoring have thus helped refine surgical techniques directed toward the preservation of cranial nerve function.

One of the most critical factors in AN surgery is the appropriate identification and respect of the cleavage planes between the AN and the facial and cochlear nerves, as well as the labyrinthine artery. Real-time monitoring has shown that most functional damage occurs during dissection along these cleavage planes. Tumor debulking has been advocated as a preliminary maneuver before dissection, with the aims of relieving the neural structures from pressure and facilitating tumor removal.^{6,7} Our personal experience in intraoperative monitoring has shown that moderate tumor pressure on the nerves and vessels during dissection and moderate traction of the nerve in a rostocaudal direction, and vice versa, do not represent significant factors of impairment of neural conduction along cochlear and facial nerves.¹²⁻¹⁵

On the other hand, maintenance of the entire block of small- to medium-sized tumor facilitates rotation of

Table 5. Auditory Results at Discharge

Preoperative Hearing	Postoperative Hearing							
	Class A		Class B		Class C		Class D	
	N	(%)	N	(%)	N	(%)	N	(%)
Debulking group (n = 33)								
Class A	4	(12.1)	2	(6.1)	2	(6.0)	7	(21.2)
Class B	—		4	(12.1)	4	(12.1)	10	(30.3)
En-bloc group (n = 29)								
Class A	4	(13.8)	3	(10.3)	2	(6.9)	3	(10.3)
Class B	—		8	(27.6)	4	(13.8)	5	(17.2)

Fisher's exact test (classes A-C vs D): $p = 0.04$

Table 6. Auditory Results at 1 Year

Preoperative Hearing	Postoperative Hearing							
	Class A		Class B		Class C		Class D	
	N	(%)	N	(%)	N	(%)	N	(%)
Debulking group (n = 33)								
Class A	4	(12.1)	3	(9.0)	2	(6.0)	6	(18.0)
Class B	—		3	(9.0)	4	(12.1)	11	(33.3)
En-bloc group (n = 24)								
Class A	3	(12.5)	3	(12.5)	2	(18.3)	2	(8.3)
Class B	—		7	(29.2)	3	(12.5)	4	(16.7)

Fisher's exact test (classes A–C vs D): $p = 0.03$

the tumor along its medial-to-lateral axis, a maneuver that enables the surgeon to visualize the virtual space between the tumor and contiguous structures. This strategy is analogous to that followed when removing encapsulated tumors in any other region of the body, eg, schwannoma of the neck, where respect of the tumor capsule is a prerequisite for a correct identification and separation of the neural (cranial nerves X–XI–XII) and vascular (internal, external carotid artery, jugular vein, etc.) structures from the tumor.

Similarly, extracapsular-extra-arachnoidal (en-bloc) removal of AN facilitates respect of vascular and neural structures furnishing an optimal identification of cleavage planes with much less bleeding. Dissecting maneuvers are thus performed with minimal traction on the nerves and under direct vision.

Maintenance of the entire tumor block particularly contributes to the optimal management of the tumor in the IAC. AN removal in the IAC fundus has proved to be highly correlated with postoperative hearing loss.¹⁵ At this level, the CN, auditory artery, and tumor are contained in a narrow space, and are sometimes hard to distinguish from one another. During this surgical step, lat-

eral-to-medial traction cannot always be avoided owing to extension of the tumor to the lateral end of the IAC. On the other hand, avulsion of the neural fibers and vessels at the level of the area cribrosa has been recognized as an important mechanism of damage during this maneuver.²¹

A series of precautions must be taken to prevent vascular damage, eg, limited use of coagulation, delicate lateral to medial tumor dissection, frequent irrigation, en-bloc removal of the tumor, etc. It must be stressed that vascular damage is often unpredictable due to the fragility of the vascular structures, the frequent involvement of the latter in the tumor, and the difficulty of finding a cleavage plane with the tumor. Further improvements in intraoperative monitoring with use of methods capable of monitoring labyrinthine blood flow may help prevent vascular damage in the future.

For these reasons, maintenance of the capsular integrity is of paramount importance in reducing bleeding and therefore coagulation during tumor removal in the IAC. Moderate tractions in a lateral-to-medial direction often enable the surgeon to visualize directly the distal end of the tumor, thus avoiding use of forceps.

The present investigation has demonstrated that the extracapsular-extra-arachnoidal removal facilitates preservation of hearing and facial nerve function. A drawback of the present study design is that patients in the two groups were operated on at different times. Therefore, improved results in patients of the en-bloc group could simply reflect the natural evolution of the learning curve. Progress in surgical skills cannot be easily distinguished from those given by the modifications of the technique. Certainly improved manual skill, increasing experience, new knowledge given by the intraoperative monitoring are inseparably linked in producing improved functional results.

En bloc removal is suitable only for tumors of small- to medium-sized diameter. Large tumors filling the CPA, causing severe displacement, infiltration, and pressure of the cranial nerves cannot be rotated or submitted to gentle retractions for dissection. Debulking is

Table 7. Complications of AN Surgery

	Debulking Group (n = 48)		En-bloc Group (n = 40)	
	N	(%)	N	(%)
Cerebellar edema	1	2.1	1	2.5
Cerebellar infarction	1	2.1	—	—
Meningitis	—	—	—	—
CSF leak	4	8.3	3	7.5
Sigmoid sinus phlebitis	1	2.1	—	—
Brainstem infarction	—	—	—	—
Death	—	—	—	—
Trigeminal dysfunction	—	—	—	—

therefore necessary to have access to the cleavage planes in the cisternal portion of the tumor. Nevertheless, en bloc removal of the most lateral part of the tumor, including the IAC portion, is recommended to increase the likelihood of facial nerve preservation.

REFERENCES

1. Dandy WE: Results of removal of acoustic tumors by the unilateral approach. *Arch Surg* 42:1026-1033, 1941
2. Bremond G, Garcin M, Magnan J: Preservation of hearing in the removal of acoustic neuroma ("minima" posterior approach by retrosigmoidal route). *J Laryngol Otol* 94:1199-1204, 1980
3. Harner SG, Laws ER: Posterior fossa approach for removal of acoustic neurinomas. *Arch Otolaryngol Head Neck Surg* 107:590-593, 1981
4. Cohen NL, Hammerschlag PE, Berg H, Ransohoff J: Acoustic neuroma surgery: An eclectic approach with emphasis on preservation of hearing. The New York University-Bellvue experience. *Ann Otol Rhinol Laryngol* 95:21-29, 1986
5. Giannotta SL, Pulec JL: Tumors of the cerebellopontine angle: Combined management by neurological and otological surgeons. *Clin Neurosurg* 34:257-466, 1988
6. Jackler RK, Pitts LH: Acoustic neuroma—the role of surgery in brain tumor management. *Clin Neurosurg* 1:199-223, 1990
7. Jannetta PJ, Møller MB, Møller AR: Technique of hearing preservation of small acoustic neuromas. *Ann Surg* 200:513-523, 1984
8. House JW, Brackmann DE: Facial nerve grading system. *Otolaryngol Head Neck Surg* 93:146-147, 1994
9. Committee on Hearing and Equilibrium guidelines for the evaluation of hearing preservation in acoustic neuroma (vestibular schwannoma). *Otolaryngol Head Neck Surg* 113:179-180, 1995
10. Ojemann RG: Management of acoustic neuromas (vestibular schwannoma). *Clin Neurosurg* 40:498-535, 1993
11. Rhoton AL: Microsurgical anatomy of acoustic neuromas. In: Sekhar LN, Janecka IP (eds): *Surgery of Cranial Base Tumors*. New York: Raven Press, 1993, pp 687-713.
12. Colletti V, Fiorino FG: Vulnerability of hearing function during acoustic neuroma surgery. *Acta Otolaryngol* 114:264-270, 1994
13. Colletti V, Fiorino FG: Continuous retrograde monitoring of the facial nerve during cerebellopontine angle surgery: Normative data. *Skull Base Surgery* 6:47-51, 1996
14. Colletti V, Fiorino FG: Continuous retrograde monitoring of the facial nerve: Preliminary experience during acoustic neuroma surgery. *Skull Base Surgery*, 1996
15. Colletti V, Fiorino FG, Sacchetto L: Iatrogenic damage of hearing during surgery for acoustic neuroma. *Skull Base Surgery*, 6:153-161, 1996.
16. Tatagiba M, Samii M, Matthies C, Al Azm M, Schonmayr R: The significance for postoperative hearing of preserving the labyrinth in acoustic neuroma surgery. *J Neurosurg* 77:677-684, 1992
17. Colletti V, Fiorino FG: Prospettive della registrazione bipolare dei potenziali d'azione del nervo cocleare nella chirurgia del basicranio. *Fracastoro* 83:157-160, 1990
18. Colletti V, Fiorino FG: Electrophysiological identification of the cochlear nerve fibers during cerebello-pontine angle surgery. *Acta Otolaryngol (Stockh)* 113:746-754, 1993
19. Colletti V, Fiorino FG: Direct bipolar recording of the cochlear nerve action potentials during cerebello-pontine angle surgery. *Am J Otol* 15:798-803, 1994
20. Møller AR: *Evoked Potentials in Intraoperative Monitoring*. Baltimore: Williams and Wilkins, 1988
21. Sekiya T, Møller AR: Avulsion rupture of the internal auditory artery during operations in the cerebellopontine angle: A study in monkeys. *Neurosurgery* 21:631-637, 1987