Microanatomical variations in the cerebellopontine angle associated with vestibular schwannomas (acoustic neuromas): a retrospective study of 1006 consecutive cases

**PRAKASH SAMPATH, M.D., DAVID RINI, M.F.A., AND DONLIN M. LONG, M.D., PH.D.**

Departments of Neurological Surgery and Art as Applied to Medicine, Johns Hopkins School of Medicine, Baltimore, Maryland

**Object.** Great advances in neuroimaging, intraoperative cranial nerve monitoring, and microsurgical technique have shifted the focus of acoustic neuroma surgery from prolonging life to preserving cranial nerve function in patients. An appreciation of the vascular and cranial nerve microanatomy and the intimate relationship between neurovascular structures and the tumor is essential to achieve optimum results. In this paper the authors analyze the microanatomical variations in location of the facial and cochlear nerves in the cerebellopontine angle (CPA) associated with acoustic neuromas and, additionally, describe the frequency of involvement of surrounding neural and vascular structures with acoustic tumors of varying size. The authors base these findings on their experience with 1006 consecutive patients who underwent surgery via a retrosigmoid or translabyrinthine approach.

**Methods.** Between July 1969 and January 1998, the senior author (D.M.L.) performed surgery in 1022 patients for acoustic neuroma: 705 (69%) via the retrosigmoid (suboccipital); 301 (29%) via the translabyrinthine; and 16 (2%) via the middle fossa approach. Patients undergoing the middle fossa approach were excluded from the study. The remaining 1006 patients were subdivided into three groups based on tumor size: Group I tumors (609 patients [61%]) were smaller than 2.5 cm; Group II tumors (244 patients [24%]) were between 2.5 and 4 cm; and Group III tumors (153 patients [15%]) were larger than 4 cm. The senior author’s operative notes were analyzed for each patient. Relevant cranial nerve and vascular “involvement” as well as anatomical location with respect to the tumor in the CPA were noted. “Involvement” was defined as adherence between neurovascular structure and tumor (or capsule), for which surgical dissection was required to free the structure. Seventh and eighth cranial nerve involvement was divided into anterior, posterior, and polar (around the upper or lower pole) locations. Anterior and posterior locations were further subdivided into upper, middle, or lower thirds of the tumor.

The most common location of the seventh cranial nerve (facial) was the anterior middle third of the tumor for all groups, although a significant number were found on the anterior superior portion. The posterior location was exceedingly rare (<1%). Interestingly, patients with smaller tumors (Group I) had an incidence (3.4%) of the seventh cranial nerve passing through the tumor itself, equal to that of patients with larger tumors. The most common location of the eighth cranial nerve complex was the anterior inferior portion of the tumor. Not surprisingly, larger tumors (Group III) had a higher incidence of involvement of fourth cranial nerve (41%), fifth cranial nerve (100%), ninth–11th cranial nerve complex (99%), and 12th cranial nerve (31%), as well as superior cerebellar artery (79%), anterior inferior cerebellar artery (AICA) trunk (91.5%), AICA branches (100%), posterior inferior cerebellar artery (PICA) trunk (59.5%), PICA branches (79%), and the vertebral artery (VA) (93.5%). A small number of patients in Group III also had AICA (3.3%), PICA (3.3%), or VA (1.3%) vessels within the tumor itself.

**Conclusions.** In this study, the authors show the great variation in anatomical location and involvement of neurovascular structures in the CPA. With this knowledge, they present certain technical lessons that may be useful in preserving nerve function during surgery and, in doing so, hope to provide neurosurgeons and neurootologists with valuable information that may help to achieve optimum outcomes in patients.

**Key Words** • vestibular schwannoma • acoustic neuroma • cerebellopontine angle • anatomy • microsurgery

Since Sir Charles Ballance first described the successful removal of an acoustic tumor in 1894, as reported by Cushing, surgeons have been challenged by lesions of the CPA and have striven to improve outcomes in patients. In recent years, great advances in neuroimaging, cranial nerve monitoring, and microsurgery have shifted the focus of acoustic neuroma surgery from prolongation of patient life to preservation of cranial nerve function, which has led to extraordinary improvements in patient outcomes, with reports from modern series of up to 90% postoperative normal or near-normal facial nerve function1,2,7,12,15,16,21,23,27,34 and 40% hearing preservation.1,3,19,22,25,33,36 A significant number of patients, however, still develop postoperative cranial nerve dysfunction. Consequently, further efforts to refine operative techniques and improve intraoperative monitoring to preserve maximum cranial nerve function continue to be made. This need is underscored by the challenge to the traditional treatment
Anatomical variations in vestibular schwannomas

of acoustic tumors, which is gross-total microsurgical resection, by newer treatment strategies such as subcapsular partial removal, conservative observation with serial imaging, and radiosurgery. The difficulty in microsurgical removal of acoustic tumors can be attributed, in part, to the great anatomical variation in the location of cranial nerve and vascular structures associated with the tumor capsule in the CPA. To date, attention has generally been directed to the location of cranial nerves distal to the tumor in the lateral aspect of the IAC after removal of the posterior meatal wall (porus acusticus). At this site, there is a consistent set of relationships of facial and vestibulocochlear nerves. The facial nerve can be identified anterior to the vertical crestae, separating the facial nerve from the superior vestibular nerve, and above the transverse plate, which separates the cochlear nerve and inferior vestibular nerve from the facial and superior vestibular nerves. Less attention has been given to the microsurgical anatomy of the brainstem surface facing an acoustic tumor. Here again, consistent landmarks on the pons, medulla, and cerebellum, such as the pontomedullary sulcus, the foramen of Luschka, the flocculus, the cerebellomedullary fissures and nerve root entry zones of the glossopharyngeal, vagus, and accessory nerves, can be very helpful in identifying displaced cranial nerves on the medial aspect of the tumor capsule. It is in the CPA itself, however, that the greatest variation in cranial nerve displacement can be found, especially for the facial and cochlear nerves. Moreover, the paucity of consistent landmarks in this area can lead to inadvertent injury of these and other important neurovascular structures.

The purpose of this paper is to identify the different anatomical locations of the facial and cochlear nerves associated with the tumor capsule of acoustic tumors in the CPA. In addition, we describe the frequency of involvement of surrounding neural and vascular structures with acoustic tumors of varying size. This in-depth analysis is based on careful documentation of cranial nerve and vascular anatomy during microsurgical removal of acoustic tumors in 1006 patients over a 29-year period. With this knowledge, we outline a number of intraoperative techniques that can help surgeons avoid injuring cranial nerves. We hope to provide neurosurgeons and neurootologists with information that may be valuable in the surgical handling of these complex lesions and may allow for the best possible outcomes in patients.

**Clinical Material and Methods**

**Patient Population**

Between July 1969 and January 1998, the senior author (D.M.L.) performed microsurgical resection of acoustic neuromas in 1022 consecutive patients. The operative approach was described in detail for each patient and was dictated by the size of the tumor and the patient’s preoperative hearing status. In patients with absent hearing and tumors of small to moderate size, a translabyrinthine approach was used. In patients with preserved hearing or moderate to large tumor size, a retrosigmoid or suboccipital approach was used. In selected patients with small intracanalicular tumors and intact hearing, a middle fossa approach was used. For this report, patients who underwent middle fossa approaches were not studied further because their tumors were small and located outside the CPA.

Lesions were resected using standard microsurgical technique. All patients undergoing suboccipital (retrosigmoid) approaches to their tumor underwent operation in the lateral (park-bench) position, as described previously. Translabyrinthine approaches were performed in conjunction with a neurootological team, as described elsewhere.

**Data Collection**

At the time of operation, the frequency of adjacent cranial nerve and arterial and venous structure involvement with the tumor capsule was identified and documented. Involvement was defined as adherence, not simply contact, between cranial nerve or vascular structure and the tumor capsule, for which surgical manipulation or dissection was required to free the structure; neurovascular structures without actual adherence to the tumor were not documented. In addition, the exact anatomical location of the facial and cochlear nerves on the tumor capsule in the CPA was noted. Operative notes were analyzed for each patient when available. The cranial nerve type was confirmed by intraoperative monitoring (that is, facial nerve EMG or BAEP monitoring) whenever possible. Otherwise, identification of the cranial nerve and/or vascular structure was based, after careful inspection, on the impression of the surgeon.

Cochlear and facial nerve involvement was divided into anterior, posterior, and polar (around the upper or lower pole) locations. In addition, anterior and posterior locations were further subdivided into upper, middle, or lower thirds of the tumor capsule. When possible, the origin of the tumor from either the superior or inferior vestibular nerve was noted. In some instances, especially with larger tumors, the origin of the lesion could not be determined.

Occasionally, a cranial nerve or blood vessel was seen to pass through the tumor itself or to become completely enfolded by the tumor. In a minority of cases, the tumor was also seen to infiltrate into cranial nerve sheaths (Fig. 1). Again, these observations were made by the senior author.

**Data Storage and Retrieval**

Charts in which the clinical course, size of tumor, anatomical locations of neurovascular structures, and facial and cochlear nerve outcomes are detailed for every patient with a vestibular schwannoma who was surgically treated between 1969 and 1998 have been stored separately. Beginning in 1993, the information in these charts has gradually been transferred to a computer database (Microsoft EXCEL; Microsoft Corp., Seattle, WA).

**Data Analysis**

To facilitate data analysis and elucidate relationships between tumor size and neurovascular structure involvement with the tumor capsule, patients with tumors in the CPA (1006 cases) were divided into three groups according to tumor size. Group I included patients with tumors...
that were smaller than 2.5 cm in maximum dimension; Group II was composed of patients with intermediate-sized tumors from 2.5 to 4 cm; and Group III included patients with tumors that were larger than 4 cm in maximum dimension. The frequency of involvement was expressed as a percentage and was then tabulated.

Results
Of the 1006 patients studied over a 29-year period, 705 (70%) were treated via the suboccipital (retrosigmoid) approach and 301 (30%) via the translabyrinthine approach. When tumor size was considered, 609 patients (61%) had small-sized tumors (Group I); 244 (24%) had intermediate-sized tumors (Group II); and 153 (15%) had large-sized tumors (Group III). More tumors appeared to arise from the superior vestibular nerve (410 patients [40.75%]) than from the inferior vestibular nerve (372 patients [37%]), although this could not be determined in 224 patients (22.26%).
Frequency of Neural Involvement

Facial Nerve. The most common location of the facial nerve was on the anterior middle third of the tumor capsule, regardless of the tumor size (Fig. 2).

In Group I patients, the facial nerve was found on the anterior middle portion of the tumor in 244 cases (40%); the anterior superior third in 204 (33.5%); the anterior inferior third in 30 (4.9%); the superior pole in 85 (14%); and the inferior pole in 15 (2.5%).
was rare and was found in only 10 patients (1.6%); five facial nerves (0.8%) were located on the posterior superior, two (0.3%) on the posterior middle, and three (0.5%) on the posterior inferior portion of the tumor. The facial nerve passed through the tumor itself in 21 patients (3.4%); in 15 (2.5%) the tumor infiltrated the nerve sheath, whereas in six (0.9%) the tumor enfolded the nerve completely. In Group II patients, the facial nerve was found on the anterior or middle portion of the tumor in 98 cases (40.2%); the anterior superior third in 81 (33.2%); the anterior inferior third in 12 (4.9%); the superior pole in 34 (13.9%); and the inferior pole in six (2.5%). Posterior location was found in six patients (2.5%); two facial nerves (0.8%) were located on the posterior superior, two (0.8%) on the posterior middle, and two (0.8%) on the posterior inferior portion of the tumor. The facial nerve passed through the tumor itself in seven patients (2.9%): in three (1.2%) the tumor infiltrated the nerve sheath, whereas in four (1.6%) the tumor enfolded the nerve completely. In Group III patients, the facial nerve was found on the anterior middle portion of the tumor in 61 cases (39.8%); the anterior superior third in 50 patients (32.7%); the anterior inferior third in eight (5.2%); the superior pole in 21 (13.7%); and the inferior pole in four (2.6%). Posterior location was found in four patients (2.6%); two facial nerves (1.3%) were located on the posterior superior, one (0.6%) on the posterior middle, and one (0.6%) on the posterior inferior location. The facial nerve passed through the tumor itself in five patients (3.3%): in four (2.6%) the tumor infiltrated the nerve sheath, whereas in one (0.6%) the tumor enfolded the nerve completely.

**Cochlear Nerve.** The cochlear nerve, not surprisingly, was found on the anterior inferior portion of the tumor in the majority of cases (Fig. 2).

In Group I, the cochlear nerve was on the anterior inferior third of the tumor in 468 patients (76.8%); the anterior middle portion in 73 (12%); and the inferior pole in 61 (10%). Posterior involvement occurred in six patients (0.9%) and only on the inferior third of the tumor. In no patient was there a superior pole or anterior superior location. Only one patient (0.1%) had tumor infiltrating the nerve. In Group II, the cochlear nerve was on the anterior inferior third of the tumor in 188 patients (77%); the anterior middle portion in 30 (12.3%); and the inferior pole in 24 (9.8%). The nerve was located posteriorly in two cases (0.8%) on the inferior aspect. Again, the nerve was not encountered on the superior pole or anterior superior location in any patient. In Group III, the cochlear nerve was on the anterior inferior third of the tumor in 118 patients (77.1%); the anterior middle portion in 26 (17%); and the inferior pole in nine (5.9%). The nerve was not encountered in a posterior, superior pole, or anterior superior location in any patient. Interestingly, the nerve did not pass through the tumor in any patient with a large- or intermediate-sized tumor.

**Trigeminal Nerve.** Trigeminal nerve involvement was quite rare in smaller tumors, occurring in only 36 (5.9%) of Group I patients. In contrast, 221 (90.6%) of Group II patients and all 153 (100%) of Group III patients had trigeminal involvement (Table 1).

**Glossopharyngeal, Vagus, and Spinal Accessory Nerves.** Surprisingly, the ninth, 10th, and 11th complex of nerves were involved in 211 patients (34.6%) with small tumors (Group I). In the tumors in Group II patients, involvement did not increase substantially and was encountered in 97 (39.8%), whereas in Group III, almost all patients (151 [98.7%] of 153) had ninth, 10th, and 11th cranial nerve complex involvement.

**Trochlear Nerve.** Involvement of the fourth cranial nerve increased as a function of tumor size and was only seen in Group II (11 patients [4.5%]) and Group III (62 patients [40.5%]) tumors.

**Hypoglossal Nerve.** The 12th cranial nerve was encountered on the anterior medial inferior portion of the tumor capsule in 13 Group II tumors (5.3%) and 47 Group III tumors (30.7%).

### Frequency of Vascular Involvement

**Superior Cerebellar Artery.** The SCA was involved with the tumor capsule only in Group III patients (121 [79.1%]).

**Anterior Inferior Cerebellar Artery.** The AICA is the artery that is most closely associated with acoustic schwannomas (Table 2). The main trunk was adherent to the tumor capsule in one Group I patient (0.16%), 91 Group II patients (37.3%), and 140 Group III patients (92%). The AICA branches, which include the labyrinthine artery that supplies the meatal segment of the facial nerve, were encountered and surgically dissected in 243 Group I patients (40%), 141 Group II patients (58%), and all 153 Group III patients (100%). The AICA or its...
Anatomical variations in vestibular schwannomas

branches was noted to traverse through the tumor itself in five Group II and five Group III patients (2.1% and 3.3%, respectively).

**Posterior Inferior Cerebellar Artery.** The PICA and its branches are important arteries to identify during surgery, because inadvertent injury can lead to serious neurological sequelae including lateral medullary syndromes (such as Wallenberg’s syndrome). The main trunk of the PICA was not involved in Group I tumors but was adherent to tumor capsules in 37 Group II and 91 Group III patients (15.2% and 59.5%, respectively). The PICA branches were involved in the tumors of 18 Group I (3%), 47 Group II (19.3%), and 121 Group III patients (79.1%). The PICA or its branches was seen to pass into the tumor itself only in large tumors (Group III), which occurred in five cases (3.3%).

**Vertebrobasilar Artery.** Involvement of the VBA increased as a function of tumor size and was only seen in Group II (54 cases [22.1%]) and Group III (143 cases [93.5%]) tumors. The VBA was seen to pass through the tumor in only two cases (1.3%) of Group III patients.

**Bridging Petrosal Veins and the Vein of the Cerebellopontine Fissure.** Bridging petrosal veins adherent to tumor were encountered in no Group I, 83 Group II (34%), and 148 Group III patients (97%) (Table 3). This vein was sacrificed in six (1%), 32 (13%), and 83 (54%) patients (Groups I, II, and III, respectively). In Groups I and II, sacrifice was always for control of hemostasis, not tumor removal; in Group III, sacrifice was performed usually in the course of tumor removal. The vein of the cerebellopontine fissure was involved in 67 patients (11%) in Group I, 163 (67%) in Group II, and 153 (100%) in Group III.

**Discussion**

Acoustic neuromas are closely related to the CPA. The CPA is a distinct V-shaped anatomical area with boundaries formed by the folding of the cerebellum around the pons and medulla and with the middle cerebellar peduncle as its floor. As the cerebellum folds around the pons, it forms two clefts that comprise the superior and inferior limbs of the cerebellopontine fissure. The two limbs merge laterally to form an apex that represents the lateral extent of the CPA. Important cranial nerves arise from the pontomedullary junction just anterior to the limbs of the cerebellopontine fissure, including the facial and vestibulocochlear nerves inferiorly and the trigeminal nerve superiorly. In addition, the AICA bifurcates in this region to form a rostral and caudal trunk that encircles the pons and sends branches to the nerves entering the IAC.

We have shown that, regardless of tumor size, the facial nerve can traverse any aspect of the tumor capsule in the CPA, but it is most commonly found anterior to the tumor in the middle third of the capsule. In a minority of cases the facial nerve may pass through the tumor itself. Interestingly, the frequency with which this occurs is not a function of tumor size and is seen equally in small and in large tumors. This great variability of facial nerve location in acoustic neuromas has important implications for safe microsurgical resection and preservation of facial nerve function postoperatively. First, because the exact location of the facial nerve on the tumor capsule in the CPA is unpredictable, internal tumor debulking should proceed with caution. We believe that the tumor can be entered most safely through a small opening in the capsule posteriorly in the middle portion (the least frequently seen location). Tumor debulking should proceed efficiently but judiciously given the small, but not insignificant, incidence of the facial nerve passing through the tumor itself. A facial nerve stimulator can sometimes provide reassurance that the tumor capsule has been penetrated safely. The tumor should only be debulked to the point at which gentle retraction of the capsule does not place undue traction on surrounding neurovascular structures. At this point, identification of cranial nerves should become a priority.

It is essential that dissection proceeds from known to unknown structures. If preservation of hearing is not a consideration and a translabyrinthine approach is being performed, identifying the facial nerve laterally near the lamina spiralis may allow better appreciation of its relationship with the tumor. If preservation of hearing is a consideration, it is sometimes easier to identify the facial nerve medial to the tumor on the brainstem surface at the zone of nerve root entry, although this is not always possible in larger tumors until considerable debulking has been performed. In the ideal circumstance, the proximal and distal portions of the facial nerve should be identified before dissecting it away from the tumor capsule. Because most of the microvascular blood supply to the facial nerve is in the subarachnoid space, it is important that dissection of the nerve from the capsule proceed in the correct plane. Overly aggressive dissection of the tumor capsule from the nerve may strip it of its vital microvascular blood supply and lead to postoperative nerve dysfunction.

In the rare circumstance in which the facial nerve is seen passing through the tumor itself, it is necessary to determine whether the tumor is actually infiltrating the nerve sheath or simply enfolding it (Fig. 1). In the former case, it is virtually impossible to dissect the tumor away from the nerve completely without causing considerable postoperative deficit. Therefore, we advocate sectioning of the entire nerve segment infiltrated by tumor, followed by immediate primary epineural neurorrhaphy.

If immediate repair is not technically feasible, then early postoperative facial nerve reconstruction should be considered. If the tumor enfolds the facial nerve, careful inspection should identify a plane at which the two capsular surfaces are interposed. This avascular plane can then be developed with blunt dissection, eventually freeing the nerve along its entire course through the tumor.

**TABLE 3**

**Frequency of involvement of venous structures with the tumor in the CPA in 1006 patients who underwent surgery for acoustic neuroma**

<table>
<thead>
<tr>
<th>Venous Structure</th>
<th>Group I (609 patients)</th>
<th>Group II (244 patients)</th>
<th>Group III (153 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>petrosal veins</td>
<td>not seen</td>
<td>83 (34%)</td>
<td>148 (97%)</td>
</tr>
<tr>
<td>sacrificed</td>
<td>6 (1%)</td>
<td>32 (13%)</td>
<td>83 (54%)</td>
</tr>
<tr>
<td>vein of cerebellopontine fissure</td>
<td>67 (11%)</td>
<td>163 (67%)</td>
<td>153 (100%)</td>
</tr>
</tbody>
</table>
An important tool in contemporary acoustic neuroma surgery is the use of facial nerve EMG studies, which greatly facilitate investigation of many of the issues discussed here. Stimulation of the facial nerve intraoperatively not only identifies its exact location but also provides the surgeon with a spatiotemporal appreciation of the tumor within the CPA. Some surgeons even prefer to use the facial nerve stimulator as a dissector to obtain continuous real-time EMG recordings. We prefer to use Rhoton dissectors because we have occasionally found that overly aggressive facial nerve stimulation can lead to decreasing EMG thresholds with resultant immediate postoperative facial nerve palsies.

The cochlear nerve has less anatomical variation than the facial nerve and is most frequently found in the anterior or inferior portion of the tumor capsule. We have shown that this nerve is never found in the superior location, regardless of tumor size. Furthermore, it is exceedingly rare that the cochlear nerve passes through the tumor itself. In recent years much attention has been placed on attempts to preserve hearing in patients with good-to-moderate preoperative function, especially regarding the inverse relationship between the size of acoustic tumors and postoperative hearing outcome. In our experience, we find that preservation of functional hearing is a realistic goal even in patients with larger tumors (Groups II and III), but predicting the patient’s ultimate hearing status on the basis of anatomical preservation of the cochlear nerve and intraoperative BAEP monitoring is much less certain. We have had circumstances in which the cochlear nerve is dissected completely free and BAEPs have remained unchanged, only to discover that the patient has poor postoperative hearing. Likewise, a very adherent cochlear nerve that requires considerable surgical manipulation to dissect free with loss of intraoperative BAEPs can sometimes result in remarkable preservation of hearing postoperatively.

Irrespective of the tumor size, however, anatomical preservation of the cochlear nerve should remain a goal of acoustic neuroma surgery when suboccipital (retrosigmoid) approaches are undertaken. To this end, we believe the cochlear nerve is best first identified on the medial aspect of the tumor capsule on the brainstem surface. Attempts should then be made to identify the nerve in the IAC, where its location is anterior and below the transverse crest, and finally to follow the nerve along the inferior portion of the tumor capsule. Again, it is important to achieve adequate tumor debulking to minimize traction injury to the nerve from capsular retraction. We agree with previous authors that tumor consistency is not an important factor in preserving cochlear nerve function. We also find that the cochlear nerve is particularly susceptible to thermal injury. Therefore, we avoid overly cold irrigation and minimize use of the laser, a tool that has become increasingly popular in recent years, especially for use in very vascular tumors. If the laser is used, it is important to use cool intermittent irrigation with continuous suction of the laser plume.

Involvement of other cranial nerves with acoustic neuromas, not surprisingly, increases with larger tumor size (Table 1). We find that the trigeminal nerve is adherent to the tumor capsule in a minority of cases, and even if postoperative dysfunction is observed, minor loss of facial sensation in the postoperative period is usually well tolerated. Nevertheless, care should be taken to preserve the trigeminal nerve motor fibers, which generally represent the inferior portion of the third division of the nerve. An EMG stimulator can help to identify these fascicles. The trochlear and hypoglossal nerves are also identifiable somatic motor nerves, which are associated with larger acoustic tumors. In our experience, these nerves usually can be dissected free of the tumor capsule anatomically intact and rarely lead to significant postoperative dysfunction.

In contrast, the glossopharyngeal, vagus, and spinal accessory nerves pose a much more difficult problem during acoustic neuroma surgery. We find, even in small tumors, a third of acoustic tumors have fascicles of the ninth, 10th, and 11th cranial nerve complex involving the facial nerve and is most frequently found in the anterior or inferior portion of the tumor capsule. We have shown that this nerve is never found in the superior location, regardless of tumor size. Furthermore, it is exceedingly rare that the cochlear nerve passes through the tumor itself. In recent years much attention has been placed on attempts to preserve hearing in patients with good-to-moderate preoperative function, especially regarding the inverse relationship between the size of acoustic tumors and postoperative hearing outcome. In our experience, we find that preservation of functional hearing is a realistic goal even in patients with larger tumors (Groups II and III), but predicting the patient’s ultimate hearing status on the basis of anatomical preservation of the cochlear nerve and intraoperative BAEP monitoring is much less certain. We have had circumstances in which the cochlear nerve is dissected completely free and BAEPs have remained unchanged, only to discover that the patient has poor postoperative hearing. Likewise, a very adherent cochlear nerve that requires considerable surgical manipulation to dissect free with loss of intraoperative BAEPs can sometimes result in remarkable preservation of hearing postoperatively.

Irrespective of the tumor size, however, anatomical preservation of the cochlear nerve should remain a goal of acoustic neuroma surgery when suboccipital (retrosigmoid) approaches are undertaken. To this end, we believe the cochlear nerve is best first identified on the medial aspect of the tumor capsule on the brainstem surface. Attempts should then be made to identify the nerve in the IAC, where its location is anterior and below the transverse crest, and finally to follow the nerve along the inferior portion of the tumor capsule. Again, it is important to achieve adequate tumor debulking to minimize traction injury to the nerve from capsular retraction. We agree with previous authors that tumor consistency is not an important factor in preserving cochlear nerve function. We also find that the cochlear nerve is particularly susceptible to thermal injury. Therefore, we avoid overly cold irrigation and minimize use of the laser, a tool that has become increasingly popular in recent years, especially for use in very vascular tumors. If the laser is used, it is important to use cool intermittent irrigation with continuous suction of the laser plume.

Involvement of other cranial nerves with acoustic neuromas, not surprisingly, increases with larger tumor size (Table 1). We find that the trigeminal nerve is adherent to the tumor capsule in a minority of cases, and even if postoperative dysfunction is observed, minor loss of facial
tumors (Table 3). Small acoustic tumors (Group I) rarely require sacrifice of petrosal veins. More care should be taken, however, with the vein of the cerebellopontine fissure. This large vessel, which is formed by the convergence of several veins draining the petrosal surface of the cerebellum, is most frequently encountered around the superior pole of the tumor capsule and, if sacrificed, may lead to cerebellar venous infarction and secondary cerebellar hemorrhage.

Conclusions

In summary, we document the exceptional anatomical variation in the location of the facial and cochlear nerves and also show the frequency of involvement of cranial nerves and vascular structures in the CPA. An appreciation of these topographic relationships can be important in avoiding postoperative cranial nerve or neurological dysfunction after microsurgical resection. There are obvious shortcomings in this study: most notably the retrospective analysis of data, the extensive time period of data collection, the lack of histological or photographic verification, and findings based on the observations of a single, albeit experienced, surgeon. However, the information in this study, based on a large group of patients, is important to neurosurgeons and neurootologists, particularly in light of emerging alternative treatment options for vestibular schwannomas, such as radiosurgery. We believe that, with a thorough understanding of the pathophysiological mechanisms and origin of cranial nerve injury and practical application of the anatomical variability discussed in this paper, microsurgery should allow cure with preservation of cranial nerve integrity for most patients with acoustic neuromas.

Acknowledgments

The authors thank Drs. Pamela Talalay and Ritu Goel for assistance in the preparation of this manuscript.

References

33. Samii M, Mathies C: Management of 1000 vestibular schwan-