Olusola K. Ogunrinde, M.D., F.R.C.S.(SN),
L. Dade Lunsford, M.D., F.A.C.S.,
John C. Flickinger, M.D., Ann Maitz, M.S.,
and Douglas Kondziolka, M.D., M.Sc., F.R.C.S.(C)

Facial Nerve Preservation and Tumor Control After Gamma Knife Radiosurgery of Unilateral Acoustic Tumors

Abstract—To assess the long-term risk of facial nerve dysfunction after unilateral acoustic tumor stereotactic radiosurgery, we retrospectively analyzed our initial experience in 98 unilateral acoustic tumor patients who were evaluated at least 2 years after treatment. This observation interval permits an analysis of both the risk of onset and the potential for recovery of facial nerve function. The overall risk of developing any degree of delayed transient or permanent postoperative facial neuropathy was 21.4% (21 of 98 patients). Only one patient undergoing radiosurgery alone had poor residual facial nerve dysfunction worse than House-Brackmann grade III. Normal facial nerve function (House-Brackmann grade I) was preserved in 95% of patients with small tumors (10 mm or less petrous-pons dimension) and in 90% of patients who had useful hearing and normal facial function preoperatively. Normal facial function was preserved in all patients with intracanalicular acoustic tumors. The risk of delayed facial neuropathy was reduced by performing radiosurgery when tumors were small (1000 mm³ or less), by enclosing the tumor within the 50% isodose volume, by using multiple small radiation isocenters, and by detailed identification of the tumor volume using stereotactic magnetic resonance imaging. (*Skull Base Surgery*, 4(2):87–92, 1994)

For almost all patients with acoustic tumors (vestibular schwannomas), the most important measure of a successful outcome is preservation of facial nerve function. Earlier detection of tumors by high-resolution neuroimaging, usage of the operating microscope, intraoperative monitoring of the facial nerve, and ultrasonic tumor debulking, have increased the likelihood of preservation of facial nerve function during microsurgical removal.

The true rates of facial nerve functional preservation after microsurgery are difficult to ascertain because of the lack of a uniform facial nerve grading system.^{1–4} Reported anatomic preservation rates range from 20 to 100%, whereas 15 to 100% have functional preservation.²⁴ Re-

cent studies substantiate the fact that results are improved if the tumor was small in size.

The high rate of tumor growth control and the carefully analyzed complication rates previously reported from the Stockholm^{25–29} and Pittsburgh^{30–41} radiosurgery centers established stereotactic radiosurgery as an effective management strategy for many patients with acoustic tumors. After gamma knife radiosurgery, functional facial nerve preservation rates vary from 92 to 100%. The present study assesses in detail those factors associated with and predictive of facial nerve functional preservation 2 years after stereotactic radiosurgery of unilateral acoustic tumors. This interval is necessary for an accurate assess-

ment of both the development of and the recovery from facial neuropathy after stereotactic radiosurgery.

MATERIALS AND METHODS

Patient Selection

Between August 1987 and December 1990, 98 patients with newly diagnosed ($n = 75$), or acoustic tumors recurrent after microsurgery ($n = 23$) underwent stereotactic radiosurgery at our institution. All patients were evaluated with high-resolution neurodiagnostic imaging, including computed tomography (CT) or magnetic resonance imaging (MRI). All had neurological and detailed facial nerve evaluations as well as audiometric studies that included speech discrimination measurement when appropriate.

Clinical Characteristics

Table 1 shows the patient characteristics; 58 (59.2%) were female. Their ages varied from 19 to 81 years (median, 55). Preoperative symptoms included partial or complete hearing loss in 95 patients (97%), imbalance and ataxia in 60 (61%), tinnitus in 33 (33.7%), facial numbness in 24 (24.5%), dysarthria in 1 (1%), and dysphagia in 2 (2%). Facial function was classified according to the House-Brackmann grading system.¹ Twenty-two patients (22.4%) had facial weakness prior to radiosurgery; six patients had grade II weakness, six had grade III, one had grade IV, four had grade V, and five had grade VI weakness (complete facial paralysis).

Radiosurgical Technique

Detailed description of our initial technique for stereotactic radiosurgery using the 201-source cobalt-60 gamma unit was described previously.^{32,34,37} Briefly, all patients were admitted for radiosurgery on the day of their scheduled procedure and stayed 6 to 18 hours after completion. On the morning of radiosurgery, a Leksell Model G stereotactic coordinate head frame (Elekta Instruments, Atlanta, GA) was applied to the patient's head under local anesthesia. A high-resolution contrast-enhanced CT or MRI scan was performed to define the target volume. Determination of stereotactic coordinates for individual irradiation isocenters was performed by the neurosurgeon. In conjunction with a medical physicist and radiation oncologist, the appropriate conformal isodose configuration, total dosage, total number of isocenters, and irradiation time were calculated using a Digital Equipment Company Microvax II computer workstation (Westminister, MA) and customized software. Currently, the digitally acquired images are transmitted by a fiberoptic ethernet

to a high-speed computer workstation (Silicon Graphics, Model 1R1S4D/220 GTX, Mountain View, CA) to complete dose planning. Dose planning was considered optimal if the entire tumor volume was enclosed within an isodose of 50% or greater (Fig. 1). Using the gamma unit, the slope of the dose fall-off is steepest at the 50% isodose.

In this study, the average extracranial tumor diameters varied from 0 mm (for intracranial tumors) to 31 mm (median, 18 mm) (Table 2). Tumor volumes varied from 100 to 14,300 mm³ (median, 3200 mm³). Maximum tumor doses varied between 24 and 50 Gy (median, 34.5 Gy) and minimum tumor doses varied between 12 and 20 Gy (median, 17.6 Gy).

Postoperative Evaluation

All patients had clinical examinations supplemented by repeat imaging studies (CT or MRI scans) at 6-month intervals for the first 2 years, then yearly for the next 2 years. In preparation for this report, telephone contact with all patients was performed to maximize follow-up. All patients in this study had a minimum of 2-year follow-up interval (range, 24 to 72 months; mean, 28 months). Using the two-tailed Fisher exact test, the observed incidence of transient facial neuropathy after radiosurgery was compared with tumor imaging characteristics (volume and contrast enhancement), maximal and marginal tumor doses, and margin isodose.

RESULTS

Patient Status

All patients returned to their preoperative level of function or employment within 3 to 5 days after radiosurgery. This functional level was maintained in all patients during the follow-up interval.

Facial Nerve Function

The preoperative, 12-, and 24-month postoperative House-Brackmann grading scores of the 98 patients are shown in Table 3. Delayed onset of any degree of facial nerve dysfunction occurred in 17 of 76 (22.4%) patients with normal preoperative facial function (grade I). Four of 22 (18%) patients with preexisting facial nerve weakness (all of whom had prior surgery) developed delayed onset exacerbation of their weakness. No significant difference in risk of delayed facial weakness was noted between patients who had residual facial weakness after prior surgery and those patients who had never undergone surgery. The overall incidence of temporary or permanent deterioration in postoperative facial nerve function was 21.4% (21 of 98 patients). The onset of facial neuropathy varied

Table 1. Patient Characteristics

Characteristics	No. Patients	Percent
Total	98	
Sex		
Male	40	40.8
Female	58	59.2
Neuroma		
Right	50	51
Left	48	49
Prior treatment		
Craniotomy or resection	23	23.5
Radiation	0	0
Signs and symptoms		
Hearing loss	95	97
Imbalance or ataxia	60	61
Tinnitus	33	33.7
Trigeminal sensory loss	24	24.5
Facial weakness	22	22.4
Dysphagia or aspiration	2	2
Dysarthria	1	1

Table 2. Preoperative Tumor Size in 98 Patients

Average Extrameatal Tumor Diameter	Tumors	
	No.	%
Intracanalicular	6	6.1
<10 mm	9	9.2
10–25 mm	75	76.5
>25 mm	8	8.2

from 2 to 16 months (median, 5 months) after radiosurgery. No patient who underwent stereotactic radiosurgery as the sole management had residual facial nerve function worse than House-Brackmann grade IV. If the patient never had attempted surgical removal, at 2 years after stereotactic radiosurgery the overall incidence of poor residual facial function (more than grade III) was 1% (Fig. 2).

We performed a statistical evaluation of the relationship between facial neuropathy and several treatment variables. Facial preservation was more likely when tumor volumes were 1000 mm³ or less and when the tumor margin was enclosed within the 50% isodose contour ($P = 0.01$). Since the ability to enclose the tumor volume within the 50% isodose represents our best attempt at dose optimization, this difference probably represents the benefit of true conformal volumetric radiation dose delivery. We found no correlation between the incidence of facial nerve dysfunction and maximal tumor dose, marginal tumor dose, subsequent change in tumor size, or preservation of hearing. These findings support the concept that (within

the doses used in this experience) tumor volume and conformal treatment planning are the most important variables predicting facial nerve risk. Tumor volume is likely related to the length of the exposed facial nerve.⁴⁰ Eighty-two patients had House-Brackmann grades I and II facial function preoperatively; unchanged facial function was maintained in 73 (overall preservation rate of 89%) 2 years after radiosurgery.

Tumor Control Assessment

The results of serial postoperative imaging studies are shown in Table 4. Intracanalicular and extracanalicular tumor measurements and calculations of average tumor diameters and tumor volumes were made as previously described.⁴¹ At 2 years, tumor size decreased in 44 (45%) and remained unchanged in 51 (52%) (tumor control rate, 97%). Using our strict criteria to determine volume reduction, regression in the average tumor diameter of 2.5 mm or more must be noted to be considered significant.⁴¹ The percentage volume reduction depends on the initial tumor volume before radiosurgery. Three patients (3%) underwent delayed microsurgical tumor excision because of documented tumor growth associated with increased local brainstem compression despite radiosurgery. The experienced microsurgeons who performed delayed microsurgery in these three patients reported that the tumor was unchanged from their expectations in two patients but more adherent to the brainstem and technically challenging in one patient. Delayed loss of tumor contrast en-

Figure 1. Diagram of the posterior fossa showing the radiosurgical dose configuration around an acoustic tumor. The intimate relationship between the tumor and adjacent trigeminal, facial, and vestibulocochlear nerves and cochlea (within the lower isodose lines) is demonstrated.

Table 3. Preoperative and 12- and 24-Month Postoperative Facial Nerve Function After Radiosurgery of 98 Acoustic Tumors

House-Brackman Grade	Description	Preoperatively		1 Year Postoperative		2 Year Postoperative	
		No.	%	No.	%	No.	%
I	Normal	76	77.6	59	60.2	61	62.2
II	Mild dysfunction	6	6.1	9	9.2	12	12.3
III	Moderate dysfunction	6	6.1	10	10.2	14	14.3
IV	Moderate to severe dysfunction	1	1.0	5	5.1	4	4.1
V	Severe dysfunction	4	4.1	8	8.2	2	2.0
VI	Total paralysis	5	5.1	7	7.1	5	5.1

hancement was observed in 58 (59.2%) patients between 4 and 21 months (median, 12 months) after radiosurgery. Figure 3 demonstrates an example of tumor regression after radiosurgery.

DISCUSSION

Major advances in acoustic tumor surgery have resulted in a significant improvement in overall postoperative results, including better facial nerve preservation rates. In the early days of acoustic tumor surgery, Dandy⁴² was unable to preserve facial nerve function. Facial nerve preservation was reported by Cairns in 1931.⁴³ In 1950, Olivecrona⁴⁴ reported the results of 217 acoustic tumor operations; anatomic facial nerve preservation was noted in 32% but function was usually lost. Cross⁴⁵ reported on 148 patients who had surgery between 1952 and 1962; only eight (5.4%) had anatomic facial nerve preservation and only four had normal facial function.

In the late 1960s the introduction of the operating microscope led to a dramatic drop in mortality rates and improvement in the rate of anatomic facial nerve preservation. More recently, three features have enhanced the rate of preservation of satisfactory facial nerve function: wider

application of the operating microscope, the development of high-resolution neuroimaging to detect tumors earlier, and intraoperative electrophysiological monitoring of the facial nerve.^{46,47}

Analysis of the current results of facial nerve preservation after microsurgery remains difficult because of variations in classification of tumor size and grading of facial nerve function. Many studies do not differentiate clearly between anatomic and functional facial preservation. Although many techniques for grading facial weakness have been advocated,¹⁻³ we adopted the House-Brackmann grading system because of its widespread acceptance.⁴

A summary of a large number of reports in the microsurgical era reveals an overall incidence of facial nerve functional preservation of approximately 84%. These results may be subdivided further by type of surgical technique: functional preservation rate of 75% for the translabyrinthine approach,¹³⁻¹⁵ 73% for the suboccipital retromastoid approach,^{11-13,16-19} and up to 98% for the middle fossa approach.^{21,22,48} Some authors believe that the better facial nerve preservation rates reported after middle fossa surgery reflect both the early identification of the facial nerve anatomically and the small size of the tumors usually selected.

Figure 2. Results of facial functional outcome, 12 and 24 months after stereotactic radiosurgery. I-VI refers to House-Brackmann's facial functional grading system.

Table 4. Postoperative Imaging Results in 98 Patients 24 Months After Radiosurgery

Variable	Effect	No. Patients	Percentage
Tumor size	Increased	3*	3.1
	Decreased	44†	44.9
	Unchanged	51	52.0
Central tumor contrast enhancement	Increased	0	0
	Decreased	58	59.2
	Unchanged	40	40.8

*Delayed microsurgical resection was carried out in these three patients.

†Average tumor diameter regression was 2.5 mm or more. Percentage volume reduction depends on preoperative tumor size.

Both large tumor size and preoperative facial weakness have been shown to be predictive factors for poor facial function recovery after microsurgical resection. When the average tumor size is greater than 2.5 cm, poorer facial nerve outcomes are more common.²² Other factors that enhance good functional outcomes include surgical experience and intraoperative electrophysiological monitoring of the facial nerve.

The results of microsurgical facial nerve functional preservation rates can be compared to those reported after stereotactic radiosurgery using gamma knife technique. Noren et al²⁹ initially reported the facial nerve preservation rate to be 83%. Slight facial weakness (House-Brackmann grade II) was observed in 6%, moderate (House-Brackmann grades III and IV) in 7%, and severe (House-Brackmann grades V and VI) in 4%. Facial nerve weakness was usually temporary, with a varying degree of improvement over time.

Initial studies from our institution reported that the risk of delayed facial neuropathy was higher than that reported by Noren et al, despite our prescription of marginal tumor doses advocated from the experience gained in Sweden.^{30–36} This led to our subsequent reduction of

tumor margin doses to 12 to 16 Gy, depending on tumor volume, doses that are currently used in Sweden as well (Noren, G: Personal communication, 1993). We also reported that the incidence of delayed trigeminal or facial neuropathy could be predicted by the length of the cranial nerve irradiated (as estimated by the tumor volume).^{40,41} The current study demonstrates that facial preservation is almost the rule when the initial tumor volumes are 1000 mm³ or less ($P = 0.01$). Facial nerve dysfunction was correlated with early MRI detection of decreased tumor contrast enhancement ($P = 0.01$). Although in some cases slight tumor enlargement was seen in association with loss of central tumor contrast enhancement, tumor regression subsequently occurred in most patients.

The pathogenesis of delayed cranial neuropathy after radiation depends on whether such neuropathy is acute (occurring within the first week), early delayed (occurring within weeks to 6 months), or late delayed (occurring several months to years later).^{49–51} Acute cranial neuropathy has been suggested to be due to direct radiation injury or edema; no patient in this series had early facial nerve deterioration. Early delayed facial neuropathy was typical of some of our patients and may be related to demyelination. Experimental models, however, have shown that degeneration, demyelination, and ischemia are probably all important in the etiology of radiation-related cranial nerve injuries.^{50,51} Further research is underway at our center to clarify the specific radiobiologic mechanisms involved in radiation-induced cranial neuropathies.

Over the first 3 years of our experience (1987–1990), our 89% (House-Brackmann grades I and II) functional facial preservation rate was comparable to those results reported by experienced microsurgeons. Over the last 3 years, using multiplanar MRI, image-integrated computer work stations for dose planning, and dose prescriptions carefully based on tumor volume relationships, the facial nerve functional preservation rate is currently 95% in patients who have normal preoperative facial function.

Figure 3. Axial plane contrast-enhanced magnetic resonance images in a 55-year-old man whose right-sided acoustic tumor (A) underwent stereotactic radiosurgery (14 Gy at margin, 50% isodose). Tumor regression was noted 11 months after radiosurgery (B).

REFERENCES

1. House JW, Brackmann DE: Facial nerve grading system. *Otolaryngol Head Neck Surg* 93:146-147, 1985
2. Yanagihara N: Grading of facial palsy. In Fisch U (ed): *Facial Nerve Surgery*. Amsterdam: Kugler Medical Publications, 1977, pp 533-535
3. Stennert E: Facial nerve paralysis scoring system. In Fisch U (ed): *Facial Nerve Surgery*. Amsterdam: Kugler Medical Publications, 1977, pp 543-547
4. House WJ: Facial nerve grading system. *Laryngoscope* 93:1056-1069, 1983
5. House WF, Luetpe CM: Evaluation and preservation of facial function: Postoperative results. In House WF, Luetpe CM (eds): *Acoustic Tumors*, vol. II. Baltimore, University Park Press, 1979, pp 89-96
6. Glasscock ME, Dickens JRR: Complications of acoustic tumor surgery. *Otolaryngol Clin North Am* 15:883-895, 1982
7. Whittaker CK, Luetpe CM: Translabyrinthine removal of large acoustic tumors. *Am J Otol* 6:155-160, 1985
8. Lye RH, Duttin J, Rawdsen RT, et al: Facial nerve preservation during surgery for removal of acoustic nerve tumors. *J Neurosurg* 57:739-746, 1982
9. Harner SG, Ebersold MJ: Management of acoustic neuromas 1978-1983. *J Neurosurg* 63:175-179, 1985
10. Smyth GDL, Campbell GR, Kerr AG: The facial nerve in acoustic neuroma surgery. *J Laryngol Otol* 96:335-346, 1982
11. Sugita K, Kobayashi S: Technical and instrumental improvements in the surgical treatment of acoustic neurinomas. *J Neurosurg* 57:747-752, 1982
12. Yasargil MG, Fox JL: The microsurgical approach to acoustic neuromas. *Surg Neurol* 2:393-398, 1974
13. DiTullio MV, Malkasian D, Rand RW: A critical comparison of neurosurgical and otolaryngological approaches to acoustic neuromas. *J Neurosurg* 48:1-12, 1978
14. House WF, Hitsberger WN: Preservation of the facial nerve in acoustic tumor surgery. *Arch Otolaryngol* 88:655-658, 1968
15. Tos M, Thomsen J: Translabyrinthine surgery of acoustic neuroma. *Acta Otolaryngol (Stockh)[Suppl]* 360:45-47, 1979
16. Devnese PP, Van Der Werf AJM, Nander Borden J: Facial nerve function after suboccipital removal of acoustic neurinoma. *Arch Otorhinolaryngol* 240:193-206, 1984
17. Drake CG: Surgical treatment of acoustic neuroma with preservation or reconstruction of the facial nerve. *J Neurosurg* 26:459-464, 1967
18. Tator CH, Nedzelski JM: Facial nerve preservation in patients with large acoustic neuromas treated by a combined middle fossa trans-tentorial translabyrinthine approach. *J Neurosurg* 57:1-7, 1982
19. Sheptak PE, Jannetta PJ: The two-stage excision of huge acoustic neurinomas. *J Neurosurg* 51:37-41, 1979
20. Tos M, Thomsen J: The price of preservation of hearing in acoustic neuroma surgery. *Ann Otol Rhinol Laryngol* 91:240-245, 1982
21. Long DM, Maltos DE, Holliday MJ: Cranial nerve preservation with acoustic tumor surgery. In Tos M, Thomsen J (eds): *Acoustic Neuroma*. Amsterdam: Kugler Publications, 1992, pp 763-765
22. Piazza F, Zini C, Gandolfi A, Sanna M, Lagher C: The problem of facial nerve anatomical and functional preservation in relation to different approaches. In Tos M, Thomsen J (eds): *Acoustic Neuroma*. Amsterdam: Kugler Publications, 1992, pp 767-770
23. Tos M, Thomsen J: Sequela after translabyrinthine removal of 400 acoustic neuromas. In Fisch U, Valvanis A, Yasargil M (eds): *Proceedings of the 6th International Symposium of Neurological Surgery of Ear and Skull Base*. Zurich: Kugler and Ghedini, 1988, pp 175-184
24. Ebersold MJ, Harner SG, Beatty CW, Harper CM Jr, Quast LM: Current results of the retrosigmoid approach to acoustic neurinoma. *J Neurosurg* 76:901-909, 1992
25. Noren G, Greitz D, Hirsch A, Ingmar L: Gamma knife radiosurgery in acoustic neuroma. In Steiner L et al (ed): *Radiosurgery: Baseline and Trends*. Raven Press, New York, 1992, pp 141-148
26. Noren G, Arndt J, Hindmarsh T, et al: Stereotactic radiosurgical treatment of acoustic neuromas. In Lunsford LD (ed): *Modern Stereotactic Neurosurgery*. Boston: Martinus Nijhoff, 1988, pp 481-489
27. Noren G, Arndt J, Hindmarsh T: Stereotactic radiosurgery in cases of acoustic neuroma: Further experiences. *Neurosurgery* 13:12-22, 1983
28. Hirsh A, Noren G: Audiological findings after stereotactic radiosurgery in acoustic neuromas. *Acta Otolaryngol (Stockh)* 106:244-251, 1988
29. Noren G, Greitz D, Hirsh A, Lax I: Gamma knife radiosurgery in acoustic neuromas. In Tos M, Thomsen J (eds): *Acoustic Neuroma*. Amsterdam: Kugler Publications, 1992, pp 289-292
30. Lunsford LD, Linskey ME: Stereotactic radiosurgery in the treatment of patients with acoustic tumors. *Otolaryngol Clin North Am* 25:471-491, 1992
31. Lunsford LD, Kondziolka D, Flickinger JC: Radiosurgery as an alternative to microsurgery of acoustic tumors. *Clin Neurosurg* 38:619-634, 1992
32. Lunsford LD, Kamerer DR, Flickinger JC: Stereotactic radiosurgery for acoustic neuromas. *Arch Otolaryngol Head Neck Surg* 116:907-909, 1990
33. Flickinger JC, Lunsford LD, Coffey RJ, et al: Radiosurgery of acoustic neuroma. *Cancer* 67:345-353, 1991
34. Linskey ME, Lunsford LD, Flickinger JC, Kondziolka D: Stereotactic radiosurgery for acoustic tumors. *Neurosurg Clin North Am* 3:191-205, 1992
35. Linskey ME, Lunsford LD, Flickinger JC: Stereotactic radiosurgery for acoustic nerve sheath tumors. In Lunsford LD (ed): *Stereotactic Radiosurgery Update*. New York: Elsevier Science Publishing, 1992, pp 321-334
36. Lunsford LD, Linskey ME, Flickinger JC: Stereotactic radiosurgery for acoustic nerve sheath tumors. In Tos M, Thomsen J (eds): *Acoustic Neuroma*. Amsterdam: Kugler Publications, 1992, pp 279-287
37. Lunsford LD, Flickinger JC, Coffey RJ: Stereotactic gamma knife radiosurgery: Initial North American experience in 207 patients. *Arch Neurol* 47:169-175, 1990
38. Lunsford LD, Flickinger JC, Lindner G, Maitz A: Stereotactic radiosurgery of the brain using the first United States 201-cobalt 60 source gamma knife. *Neurosurgery* 24:151-159, 1989
39. Lunsford LD, Maitz A, Lindner G: First United States 201 source cobalt-60 gamma knife unit for radiosurgery. *Appl Neurophysiol* 50:253-256, 1987
40. Linskey ME, Flickinger JC, Lunsford LD: Cranial nerve length predicts the risk of delayed facial and trigeminal neuropathies after acoustic tumor radiosurgery. *Int J Radiat Oncol Biol Phys* 25:227-233, 1993
41. Linskey ME, Lunsford LD, Flickinger JC: Neuroimaging of acoustic nerve sheath tumors after stereotactic radiosurgery. *AJNR* 12:1165-1175, 1991
42. Dandy WE: Operation for the total removal of cerebellopontine (acoustic) tumors. *Surg Gynecol Obstet* 41:129-148, 1925
43. Cairns H: Acoustic neuroma of right cerebellopontine angle. Complete removal. Spontaneous recovery from postoperative facial palsy. *Proc R Soc Med* 25:7-12, 1931
44. Olivecruna H: Analysis of results of complete and partial removal of acoustic neuromas. *J Neurol* 13:271-272, 1950
45. Cross JP: Unilateral neurilemmomas of the 8th cranial nerve: Then and now. *Am J Otol* 3:28-34, 1981
46. Moller AR, Jannetta PJ: Preservation of facial function during removal of acoustic neuromas: Use of monopolar constant-voltage stimulation and EMG. *J Neurosurg* 61:757-760, 1984
47. Delgado TE, Buchleit WA, Rosenholtz HR, et al: Intraoperative monitoring of facial muscle evoked responses obtained by intracranial stimulation of the facial nerve: A more accurate technique for facial nerve dissection. *Neurosurgery* 4:418-421, 1979
48. Shelton C, Brackmann DE, House WF, Hitselberger WE: Middle fossa acoustic tumor surgery: Results in 106 cases. *Laryngoscope* 99:405-408, 1989
49. Shelton GE, Wara WM, Smith V: Therapeutic irradiation and brain injury. *Int J Radiat Oncol Biol Phys* 6:1215-1228, 1980
50. Bergstrom R: Changes in peripheral nerve tissue after irradiation with high energy protons. *Acta Radiol* 58:301-312, 1962
51. Gardner G, Robertson JH: Hearing preservation in unilateral acoustic neuroma surgery. *Ann Otol Rhinol Laryngol* 97:55-66, 1988

The authors thank David Bissonette, PA-C, for his management of the computer database; Lisa Svitek, Phyllis Shoemaker, MaryAnn Vincenzini, and the staff of the Specialized Neurosurgical Center for assistance with preparation of this manuscript; and Pat Fritz for editorial assistance.