Acoustic Neuroma: Outcome of Surgical Resection and Study on the Anatomy of Facial and Cochlear Nerves

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Abstract

The treatment of acoustic neuroma (vestibular schwannoma) has evolvedgreatly. In this report, we studied the history of acoustic tumour surgery, and documented the value of technical advances in benefiting patients. We also present our outcome of surgery for this benign tumour in support of its use as the treatment of choice. In 611 patients undergoing initial surgery at Johns Hopkins from 1973-1994, complete resection was obtained in all but one case (intentional), and permanent morbidity and mortality rate was 0.3%. Including temporary morbidity, the rate was 3.8%. Tumour recurrence was seen in only 0.8% of cases. Thefacial nerve was preserved in 97.6% and function at one-year was House -Brackmann grade 1 or 2 in 89.7%. Lastly, we present results of an anatomical study localizing the nerves and vessels, and the frequency of involvement by tumour, associated with acoustic neuromas in 1006 surgical cases. We continue to offer surgery as the best treatment option for the majority of ourpatients, andprefer the suboccipital route because of its unrestricted access to all posterior fossa structures, and ability to preserve hearing.

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Introduction

Acoustic neuroma (vestibular schwannoma) patients have greatly benefited from technical advances in neurosurgery. In fact, the evolution of acoustic neuroma surgery is a microcosm of the development of neurosurgery overall. In the modern era, magnetic resonance imaging allows early diagnosis of these neoplasms, increasing the potential for curative resection without new neurological deficits. Even so, this procedure continues to be one of the most difficult for the neurosurgeon to master. Adjacent nerves and vessels are delicate, and even modest facial or swallowing dysfunction is poorly tolerated by many patients.

With the appearance of focused radiation as a new treatment alternative, surgical approaches to the cerebellopontine angle (CPA) are being reassessed.[1-3] We believe that the low incidence of recurrence, combined with the low morbidity and high rates of facial nerve preservation documented in our experience, support continued use of surgery as the treatment of choice for most patients.[4-6] We also believe that understanding the microanatomical distortions occurring with acoustic neuromas improves surgical results. In support of our position, we review our results in the surgical treatment of this benign neoplasm, and a study of the microanatomical variations associated with it.

Materials and Methods

Historical Review

All case reports and series in the literature addressing the operative treatment of acoustic neuroma were reviewed (from 1890, when this surgery first began, to 1990). The full list reviewed is found in reference number seven. The available results were analyzed by dividing them into five eras: pioneer era (1890-1925), curative era (1925-1960), facial nerve preservation era (1960-1974), cochlear nerve preservation era (from 1975 on), focused radiation era (from 1969 on).[7]

Clinical Outcome Study

Medical records of all patients surgically treated for acoustic neuroma at the Johns Hopkins Hospital from 1973 to 1994 were reviewed. In addition to overall outcomes, the primary purpose was to assess what the Acoustic Neuroma Society reports as the most concerning issue to patients: facial nerve outcome after initial surgery.[8] Thus, the following were excluded: the rare patients with preoperative facial dysfunction, patients with previous CPA surgery or other cranial nerve schwannomas, and cases of inadequate follow-up. Fa-

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cial nerve function was assessed by the House-Brackmann scale.[9] All procedures were performed by a combined neurosurgery/neurootology team. Tumours were classified by size according to maximum extrameatal diameter as small (<2.5 cm), medium (2.5-4 cm), or large (>4 cm). Six hundred eleven cases met the study criteria.[5]

Microanatomical Analysis

As the purpose of this study was to determine how the presence of a tumour alters the anatomy within the CPA, more cases were eligible. All patients undergoing microsurgical resection of acoustic neuromas by the senior author (DML) from 1969 to 1997 were studied. Middle fossa approaches were excluded due to the extremely small tumour size, leaving 1006 cases for study. Tumours were classified by size as noted above. The location of the seventh and cochlear nerves were documented in each case. In the latter part of the series, nerve identity was also verified by intraoperative monitoring. Eight locations were defined: anterior or posterior (with upper, middle or lower thirds for each) and polar (upper or lower). For others nerves and vessels, involvement by tumour was documented by the surgeon for each case in which it occurred. "Involvement" was defined as intimate contact with the tumour capsule requiring dissection to free the nerve/vessel.[10]

Results

The History of Acoustic Neuroma Surgery (Table I)

The Pioneer *Eva,* 1890-Z 925: Not unexpectedly, this era began with unsuccessful attempts at surgery. Ballance is often credited with the first successful removal of an acoustic neuroma, but it should be noted that Cushing suspected this to be a meningioma.[11] He identified the first successful removal as Annandale's in 1925.[12] Both the suboccipital and translabyrinthine approaches were used in this era. These patients presented with very large tumours, significant deficits and undoubtedly frequent hydrocephalus. The goal of surgery was limited to attempts at preserving life. In this setting, the accomplishment of Harvey Cushing becomes dramatic. The largest series of the era (Horsely-15 cases, Eiselsberg-17 cases, Krause-31 cases, Tooth-l 7 cases, and Henschen-70 cases) reported a mortality of over 70%.[13-18] In contrast, Cushing's mortality rate was 15.4% for 39 cases in this era.[12] This figure dropped to 4.0% in his last 50 cases.[19] This improvement was achieved by using the technique of intracapsular debulking, which saved life at the expense of incomplete tumour resection. Even then, the 5-year survival rate of Cushing's patients was as high as 56% (as reported by List).[20]

TABLE I: ERAS IN THE DEVELOPMENT OF ACOUSTIC NEUROMA SURGERY

Years	Era	Goal of treatment
1890-I 925	Pioneer	Save life
1925- 1960	Curative	Complete tumour removal
1961-1974	Seventh nerve	Avoid facial palsy
1975 on	Eighth nerve	Preserve hearing
1969 on	Focused radiation	Control tumour with low procedural risk

The Curative Eva, 1925-1960: In this era, several surgeons began to improve the outcome of patients while achieving total or near-total tumour resections. The translabyrinthine approach seems to have been abandoned as all reports used the suboccipital route. The major advance was made by Walter Dandy, reporting five total excisions with no mortality in 1925.[13] By 1935, he was using a unilateral suboccipital (SOC) approach, rather than the bilateral method of Cushing.[21] His success can be attributed to CSF drainage from the lateral ventricles and cisterna magna, resecting the lateral cerebellum as needed, and unroofing the internal acoustic meatus for removal of the intracanalicular tumour extension. These improvements came at the expense of losing the seventh nerve in all but 6% of Dandy's patients, and his mortality was higher.[21,22] Many larger series were reported, most with seventh nerve preservation rates of less than 20%.[23-25] Olivecrona,[26] however, was advancing treatment by preserving this nerve in **32%** of cases.

The Seventh Nerve Era, 1961-1974: The great advances occurring during this period are attributable to the introduction of the surgical microscope. The first application to acoustic neuroma (and the first in neurosurgery) was in the middle fossa approach by the otolaryngologist House, in conjunction with the neurosurgeon Doyle.[27,28] House also revived the translabyrinthine (TL) approach for tumours of all sizes, and advanced early diagnosis by promoting full neurootological evaluation of every patient with hearing loss, tinnitus, or vertigo.[28,29] This era saw the improvement in acoustic surgery using either the TL or SOC approach. Cumulative results of the SOC approach were a mortality of 18%, complete resections in 79%, and seventh nerve preservation in 49%. The TL results were even better, having 6% mortality, 88% complete resection rate, and anatomically preserving 92% of facial nerves. The success of the TL approach came at the expense of sacrificing hearing, which becomes increasingly relevant with further technical refinements and earlier diagnosis.

The Eighth Nerve *Eva,* 1975 *on*: The overall improvements of this era are seen in the cumulative mortality of 1.8%, total resection rate of 96%, and seventh nerve preservation rate of 83%. Also in this era, these rates no longer differ between the SOC and TL approach. Although one hesitates to say these problems are completely solved, nonetheless attention has turned to hearing preservation as the next goal. Even with early

diagnosis, a minority of patients are realistic candidates for meaningful preservation of hearing. Tumours need to be small (minimal to no extracanalicular extension) and preoperative hearing needs to be reasonable (discrimination scores at least 50%, reception threshold maximum 50 dB).[30,31] Cumulative results from this era through 1989 show anatomic cochlear nerve preservation in 24% of patients, preservation of any degree of hearing in 15%, and functional hearing in 10%. More recent series from this decade that include only the most favourable candidates have reported much higher rates of functional hearing preservation, exceeding 50% in certain subgroups.[32-35]

Focused Radiation Era, 1969 on: The next advance in treatment was the demonstration that high doses of radiation focused on the tumour could control growth.[36] This approach is continuing to evolve technically,[37] but it offers treatment to patients who might otherwise not be considered candidates if surgery were the only option. In some cases, including elderly or medically infirm, it may be the best option. Reported control rates (lack of growth) before 1990 are generally in the 80% range. More recent reports have higher control rates but follow-up is necessarily shorter.[2,3,38,39] Since significant tumour shrinkage is rare, these rates may change with prolonged follow-up. In addition, there is a small risk for radiation-induced malignancy that may not be fully appreciated yet, because of the long latency and the fact that only small numbers of patients are available from early in the experience with this modality. Patients do avoid the general risks of posterior fossa surgery, but continue to have a significant incidence of facial nerve palsy (usually in the 20% to 30% range), despite that fact that only small tumours are eligible for this treatment method.[38-42] Hearing preservation is usually <50%, with deterioration tending to occur in a delayed fashion.[38-42]

Results of the Hopkins Series (Table II)

Our focus is on surgical treatment, due to our belief that current techniques offer complete removal with very low morbidity. To support this contention, we analyzed the 611 patients surgically treated for acoustic neuroma at Johns Hopkins from 1973 to 1994. The median age was48.5 years. The approaches were as follows: retrosigmoid suboccipital (SOC) 72.7%, presigmoid translabyrinthine (TL) 25.5%, and middle fossa (MF) 1.8%.

Overall results: All patients had complete tumour resection, with one exception of an elderly patient in whom subtotal removal was planned preoperatively. One perioperative death (0.16%) occurred early in the series. Six patients (0.98%) experienced significant morbidity: four returned to surgery for cerebellar haematomas, one had a capsular haemorrhage of unknown cause, one had an ischaemic infarct. Five of these made a good recovery with one (0.16%) having permanent hemiparesis. Thus our overall permanent morbidity and mortality rate was 0.32%.

TABLE II: RESULTS OF THE HOPKINS SERIES

Characteristic	n (%)
Patients	611
Age – mean 5 1.4 years	
– range 14 to 83 years	
Complete resection	610
Mortality	1 (0.16%)
Permanent morbidity	1 (0.16%)
Total morbidity and mortality	(3.76%)
7th nerve preserved	(97.6%)
House-Brackmann Grade l-2 at 1 year	(89.7%)

Other temporary complications included 6 (0.98%) reoperations for CSF leak and 10 (1.64%) cases of meningitis successfully treated with antibiotics. If all these patients were included, the morbidity and mortality rate was 3.76%.

Patients were followed with annual MR scans for 5 years. Tumour recurrence was seen in 5 patients (0.82%).

Facial nerve results: Anatomical preservation was achieved in 97.6% of patients. Of the 15 (2.45%) nerve transections, 8 underwent immediate end-to-end repair, with 5 recovering to House-Brackmann (HB) grade 3 or 4 at one year. When examined by approach, poor function at six months (HB grade 5 or 6) was seen in 1.58% (n = 7) by the SOC approach, and 2.5% (n = 4) by the TL approach. Larger tumours had a higher incidence of poor function than smaller ones. Facial function also improved over time. Immediately after surgery, 62.1% of patients were HB grade 1 or 2. Of the 536 patients evaluated at one year, 89.7% were HB grade 1 or 2, with 8.9% grade 3-4, and only 1.3% grade 5-6.

Microanatomical Issues in Tumour Resection

Good outcomes from technically challenging surgery are facilitated by a clear understanding of the regional anatomy. Studies of cadaveric specimens are helpful to a degree, but pathological anatomy is more relevant yet more difficult to obtain. The presence of a neoplasm by definition distorts and changes the anatomy learned on normal cadavers. Unfortunately, MRI is not yet advanced enough to identify the facial nerve in relation to a tumour. If the surgeon did know where one is likely to find a nerve after it is displaced, it is more likely to be spared. This is the definition of surgical experience, which is known to improve outcome.[43] Thus, we analyzed the experience of the senior author (DML) in this regard.

The 1006 tumours included in this study were all resected by the senior author from 1969 to 1997. The approach used was SOC in 70%, and TL in 30%. The location of the facial and cochlear nerves was noted in

every case, as was any structure involved by the tumour (as defined in Materials and Methods). Tumours were small (<2.5 cm) in 61%, moderate (2.5-4 cm) in 24%, and large (>4 cm) in 15%.

Facial *nerve* location (Table *III)*: Locations were similar for tumours of all sizes, with exceptions as noted below. The most common location was in the anterior middle third of the tumour capsule, with a significant number in an anterior, superior location. Posterior location did occur, though rare (<1%), and was seen with all size tumours. Therefore, we always use facial nerve monitoring to stimulate the posterior capsule prior to debulking. In fact, the facial nerve was found at least once in every location for every size tumour. Instances of the facial nerve passing through the tumour substance were surprisingly similar in small and large tumours (3.4%).

Cochlear nerve location (Table *III)*: The most common location was anterior-inferior. Tumour infiltration was seen in only one case, interestingly in a small tumour. The cochlear nerve was never seen in a superior location or in the posterior-middle site. Thus, in attempts to preserve hearing, questionable structures located superiorly are unlikely to represent the nerve, while tissue in most other locations should be respected until the nerve is definitively identified.

Others *nerves and vessels (Table IV):* Involvement of these structures in the tumour capsule, such that dissection was required to free them, occurred in direct relation to tumour size as expected. All large tumours required dissection to free the trigeminal nerve. While nearly all large tumours also required dissection of nerves IX-X-XI, surprisingly, small tumours required this dissection in one-third of cases.

The anterior inferior cerebellar artery (AICA) is most intimately related to acoustic tumours, since its normal course loops into the IAC and wraps around the VII-VIII nerve complex. Sparing it is of vital importance, including the small branches in the IAC region. Important branches include the labyrinthine artery supplying the VII-VIII complex, disruption of which leads to complete, permanent loss of hearing, and the recurrent perforating branch coursing back to the brainstem.[44] Even in small tumours, labyrinthine artery involvement was seen in 40% of cases. This vessel alone accounts for much of the difficulty in preserving useful hearing when the tumour has significant extracanalicular extension. Having AICA or its branches course through the tumour substance is uncommon, occurring in 3.3% of large tumours only.

Venous structures generally do not cause difficulty. In

TABLEIII: LOCATION OF FACIAL AND COCHLEAR NERVES ON THE CAPSULE OF ACOUSTIC NEUROMAS

Location	Tumour size		
	Small (%) n = 609	Moderate (%) n = 244	Large (%) n= 153
Facial nerve:			
Anterior			
Superior	33.5	33.2	32.7
Middle	40.0	40.2	39.8
Inferior	4.9	4.9	5.3
Posterior			
Superior	0.8	0.8	1.3
Middle	0.3	0.8	0.7
Inferior	0.5	0.8	0.7
Polar			
Superior	14.0	13.9	13.7
Inferior	2.5	2.5	2.6
Through tumour	3.4	2.9	3.3
Cochlear nerve:			
Anterior			
Superior	0	0	0
Middle	12.0	12.3	17.0
Inferior	76.8	77.0	77.1
Posterior			
Superior	0	0	0
Middle	0	0	0
Inferior	I.0	0.8	0
Polar			
Superior	0	0	0
Inferior	10.0	9.8	5.9
Through tumour	0.2	0	0

TABLE IV: FREQUENCY OF INVOLVEMENT OF OTHER CRANIAL NERVES AND VESSELS IN THE CEREBELLOPONTINE ANGLE WITH ACOUSTIC TUMOURS

Structure	Tumour size		
	Small (%) n = 609	Moderate (%) n = 244	Large (%) n= 153
Vth nerve	5.9	90.6	100
IVth nerve	not seen	4.5	40.4
XIIth nerve	not seen	5.3	30.7
IX-X-XI nerves	34.6	39.8	98.7
SCA	not seen	not seen	79.1
AICA			
Main trunk	0.2	37.3	91.5
Branches	39.9	57.8	100
Intratumoural	not seen	2.0	3.3
PICA			
Main trunk	not seen	15.2	59.2
Branches	3.0	19.3	79.1
Intratumoural	not seen	not seen	3.3
Vert-basilar a.	not seen	22.1	93.5
Intratumoural	not seen	not seen	1.3
Petrosal vein	not seen	34.0	96.7
Sacrificed	1.0	29.9	54.2
Vein of CP fissure	11.0	66.8	100

AICA: anterior inferior cerebellar artery; CP: cerebellopontine; PICA: posterior inferior cerebellar artery; SCA: superior cerebellar artery; Vert-basilar a.: vertebro-basilar artery complex

particular, sacrifice of the petrosal vein is well tolerated. We believe sacrifice of the vein of the cerebellopontine fissure, however, can lead to venous congestion with oedema and haemorrhage. We are careful to preserve any veins on the posterior aspect of the tumour for this reason.

Discussion

Choices in Approaching the Internal Auditory Canal (Table V)

The goal of every approach is the internal auditory canal (IAC). This is the site of origin for acoustic neuromas, and must be explored to obtain complete resection. The three standard approaches are: middle fossa (MF), presigmoid translabyrinthine (TL), and retrosigmoid suboccipital (SOC).

Middle fossa approach: This extradural approach under the temporal lobe to identify the IAC from above using well-defined bony landmarks on the middle fossa floor. It has been the most successful approach for hearing preservation, but can only be used in patients with essentially intracanalicular tumours.[35] There is a theoretical risk of temporal lobe injury, and some have voiced concern over facial nerve injury since it may be interposed between the surgeon and the tumour in a tight space.[45] The problems are very infrequent in experienced hands, but another problem is the unfamiliarity of the approach for most surgeons. We have used this approach in the few patients in our series having the classical indication: preserved hearing and an intracanalicular tumour.

Translabyrinthine approach: This approach involves drilling out the mastoid air cells and labyrinth to expose the CPA anterior to the sigmoid sinus.[46] The main advantage is minimizing retraction of the brain stem, and the obvious disadvantage is complete loss of hearing. Another theoretical disadvantage is that the brain stem is not seen until late in the dissection of large tumours.[47] While some have posited its use only in moderately sized tumours, we have used it regardless of size with excellent results. We still, however, prefer the suboccipital approach for very large tumours, and if significant hearing is preserved.

Suboccipital approach: This approach utilizes a retrosigmoid craniotomy for unilateral entry into the posterior fossa.[48] Its potential disadvantages include brain retraction and poor visualization of the most lateral portion of the IAC.[49] We believe the advantages of unrestricted access to all areas of the posterior fossa, familiarity with the approach, and ability to save hearing are more important and we use this approach in the majority of cases. With CSF drainage from the cisterna magna, and early intracapsular debulking, we and others have had minimal problems related to brain retraction.[50] Similarly, our otology team has had minimal difficulty with reaching the lateral IAC for complete tumour resection, verified by our low recurrence rate. Age, per se, does not influence the choice of approach or the decision for surgery as opposed to other treatments. A poor general medical condition, however, may lead to a recommendation for radiosurgery in small tumours, or a translabyrinthine approach in larger tumours that would otherwise be done via the suboccipital route.

TABLE V: APPROACHES TO THE INTERNAL AUDITORY CANAL

Approach	Advantages	Disadvantages
Middle fossa	Hearing preservation	Restricted to small tumours Temporal lobe retraction Unfamiliar approach
Translabyrinthine	No brain retraction	Complete hearing loss
Suboccipital	Unrestricted posterior Fossa access Surgeon familiarity	Cerebellar retraction Lateral IAC access

IAC: internal auditory canal

Cranial Nerve Preservation

The goal of modern acoustic neuroma treatment by any method should be complete eradication of the tumour without causing any new deficits. Currently, the surgical approach in experienced hands comes closest to achieving this goal.

Facial nerve preservu tion: Our historical analysis of acoustic neuroma surgery documents the effectiveness of technical advances in improving patient outcome regarding facial palsy. All surgeons now accept the inestimable value of the operating microscope. We also believe electrophysiological monitoring is important and further advances in this area should be promoted to increase our ability to identify the nerve early in the dissection. Though our series did not specifically analyze the results of nerve monitoring, it is our impression that lack of a response to stimulation is associated with a lower rate of facial nerve recovery. A large proportion of nerves, however, will recover if they are anatomically intact.

We believe our favourable clinical results are due to a number of additional factors we have learned during the experience. Early and generous internal debulking of the tumour mass cannot be overemphasized. We perform this manoeuvre even in small tumours, to leave a thin layer of tumour capsule. Prior to initial capsular incision, the site is always stimulated to identify a rare facial nerve in a posterior position. Further stimulation is also done periodically within the tumour during debulking to identify a rare intratumoural nerve, or more often, to identify areas where thin capsule may be adjacent to the external nerve. The resulting thin layer is

then carefully dissected off the nerve by sharp techniques to minimize manipulation of the nerve itself. Preserving the vascular supply is key, so any small bleeders directly adjacent to the nerve are never electrocoagulated, but are easily controlled with cotton or Gelfoam and time. Only microsuction devices are used, and then only with cotton between their tips and any neural tissue. We always proceed from normal to abnormal structures in dissecting the capsule, and preservation of the proper arachnoid plane is also critical to preserving the nerve. In neurofibromatosis type II patients, we feel that the nerve is more adherent to the tumour mass and outcome is slightly worse. We have not, however, performed a detailed analysis of this small subgroup.

Proper management of the patient with facial palsy is crucial to avoid exposure keratitis. If the patient can still close the lid, eyedrops and daily inspection are usually all that is needed until further recovery ensues. For more pronounced weakness, we rely primarily on ophthalmic lubricants and moisture-capturing eye coverings with good results. Tarsorrhaphy is needed in only a few percent of patients, primarily those with concomitant fifth nerve sensory loss. The lack of cornea1 sensation in these patients increases their risk. For severe palsies, we use clinical examination and serial EMG to assess facial recovery. If no recovery is evident at one year, patients are considered for reanimation surgery (usually a hypoglossal-facial anastomosis). In cases of facial nerve transection at initial surgery without intracranial repair, we proceed with a hypoglossal-facial anastomosis within a few weeks.

The microanatomical data are presented in an attempt to translate our large surgical experience in a way that benefits the younger surgeon. Knowing where to seek all the structures of the posterior fossa in the setting of an acoustic tumour may be advantageous in that regard. Surgeons should first seek the nerve in an anterior location. This is best done by identifying normal nerve either at the brainstem, or laterally after drilling the IAC, and following it to determine its precise course. For the best results, both ends are identified prior to final dissection of the thinned capsule. Our specific findings of posterior and intratumoural facial nerves directly lead to the technical recommendations detailed above. If a nerve is transected, attempts at immediate end-to-end repair are warranted by a favourable outcome in many cases.

Hearing *preservation:* Hearing preservation is the challenge now at the forefront of acoustic neuroma treatment. Unfortunately, focused radiation has not been the solution, since patients with small tumours still lose hearing frequently, and the latest results are somewhat better but with lower doses that may ultimately lead to recurrence.[51] Since the major factors predictive of hearing preservation are small tumour size and excellent preoperative audition, even earlier diagnosis will ultimately improve results.[31] Currently, only a small percentage of patients have a reasonable chance of completing treatment with useful hearing.[30,31,33,52,53]

We attempt to preserve hearing in every case with reasonable hearing preoperatively. We acknowledge that with larger tumours this is less likely, but hearing is never saved unless it is attempted and we have had isolated cases of preserved hearing in larger tumours. Thus, we choose the suboccipital approach in some cases that others may perform by the translabyrinthine route. We use the same meticulous techniques as described above. The advantages of careful technique for hearing function are supported by a recent experimental study.[54] We attempt to work from medial to lateral to avoid traction on the small cochlear fibres exiting the spiralis foraminus at the lateral end of the IAC. In these cases we avoid cold irrigation, not only as a general principle, but because it may disrupt electrophysiological monitoring. The exception is during drilling of the IAC, when cool (room temperature) irrigation is used to avoid excessive heat. Care is taken that drilling the IAC does not extend too far lateral with injury to the labyrinth.[49] Even with these precautions, some nerves are unsalvageable due to tumour invasion.[55] Other patients, as seen with radiosurgery, will experience later hearing decline without tumour recurrence.[56] Thus, additional work must be encouraged to facilitate meeting this current challenge.

Conclusions

Surgery for acoustic neuroma has advanced greatly since its inception. We believe it is still the treatment of choice for this benign tumour; however, each case must be individually assessed as some patients with small tumours may benefit more from a focused radiotherapy technique. Such patients include the elderly, the medically infirm in whom general risks of surgery are high, recurrent tumours, and those who simply prefer this approach. Intentional subtotal resection, with or without focused radiation, may play a small role in the medically infirm with large tumours. For all others, especially if hearing is preserved, we offer surgery as our primary recommendation.

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