Complications and Sequelae in Acoustic Neuroma Surgery

Andrés Coca,[a] Justo R. Gómez,[a] José L. Llorente,[a,b] Juan P. Rodrigo,[a,b] Faustino Núñez,[a] María A. Sevilla,[a] and Carlos Suáreza,[a,b]
[a]Servicio de Otorrinolaringología, Hospital Universitario Central de Asturias, Oviedo, Asturias, Spain
[b]Instituto Universitario de Oncología del Principado de Asturias, Oviedo, Asturias, Spain

Objective: To evaluate the complications and sequelae of acoustic neuroma surgery, according to tumour size.
Patents and method: A retrospective analysis of 120 patients who underwent microsurgical resection of vestibular schwannomas between November 1994 and September 2006 was undertaken. Tumour size, extent of removal, preservation of facial and cochlear nerves, complications, and sequelae were considered. The degree of hearing preservation after surgery was determined by the Gardner-Robertson classification.
Results: There were 39 small (<1.5 cm), 59 medium (1.5-3 cm), and 22 large tumours (>3 cm). Gross total resection was accomplished in 106 cases (88.3%). The facial nerve was anatomically and functionally preserved in 103 cases on long-term follow-up (85.4%). The cochlear nerve was functionally preserved (Gardner-Robertson class 1 and 2) in 54.4% of the small tumours with useful preoperative hearing. Two patients died due to postoperative complications (mortality rate, 1.6%), and 15 (12.5%) developed a CSF leak.
Conclusions: Despite the progress in the surgical treatment of acoustic neuromas, a considerable rate of complications and sequelae still remains. Therefore, there is a need to balance pros and cons of surgery in each patient according to the concurrent circumstances, as well as to consider other therapeutic strategies such as radiosurgery or a wait-and-see policy.

Key words: Acoustic neuroma. Facial nerve. Schwannoma. Neuroma. Cerebellopontine angle. Hearing preservation. Intraoperative monitoring.

Complicaciones y secuelas en la cirugía de los neurinomas del acústico

Objetivo: Evaluar las complicaciones y secuelas de la cirugía del schwannoma vestibular, en virtud del tamaño tumoral.
Pacientes y método: Se realiza un estudio retrospectivo de 120 pacientes afectos de neurinomas del acústico, a los que se practicó resección microquirúrgica de la lesión entre noviembre de 1994 y septiembre de 2006. Se recogen datos del tamaño tumoral, la extensión de la resección, la preservación de los nervios facial y coclear, las complicaciones y las secuelas vestibulares. Se determina el grado de preservación de la audición según la clasificación de Gardner-Robertson.
Resultados: Entre las citadas fechas se intervinieron en 39 neurinomas pequeños (< 1,5 cm), 59 de tamaño medio (1,5-3 cm) y 22 grandes (> 3 cm). La resección total de la lesión se consiguió en 106 (88,3%) de los 120 casos. Se alcanzó una conservación anatómica del nervio facial y funcional en el seguimiento a largo plazo en 103 (85,4%). La función del nervio coclear se conservó (grados 1 y 2 de la clasificación de Gardner-Robertson) en el 54,4% de los schwannomas de menos de 1,5 cm de diámetro con audición válida. Fallecieron 2 pacientes por complicaciones postoperatorias (tasa de mortalidad, 1,6%) y en 15 (12,5%) se desarrolló una fístula de líquido cefalorraquídeo.
Conclusiones: Pese a la notable mejora en los resultados de la cirugía de los neurinomas del acústico, todavía presenta una tasa apreciable de complicaciones y secuelas. Por ello debe sopesarse en cada caso particular su realización en función de las circunstancias concurrentes y valorar la posibilidad de otras alternativas como la conducta expectante o la radiocirugía.

Palabras clave: Neurinoma del acústico. Nervio facial. Schwannoma. Neurinoma. Ángulo pontocerebeloso. Preservación auditiva. Monitorización intraoperatoria.

The authors have not indicated any conflict of interest.

Correspondence: Dr. A. Coca Pelaz.
Valdés, 10, 2.º E. 33012 Oviedo. Asturias. España.
E-mail: acocapelaz@yahoo.es

Received June 22, 2007.
Accepted for publication July 10, 2007.

INTRODUCTION

Acoustic neuromas represent 9% of intracranial tumours and more than half the tumours of the posterior fossa. The age of greatest incidence is between 30 and 40 years of age, and it predominantly affects women.

They begin to grow in the inner auditory canal and later evolve towards the cerebellopontine angle, compromising the neighbouring vascular nerve structures. They are manifested by cochlear and/or vestibular symptoms although they may, depending on their size, produce endocranial symptoms or affect other cranial pairs.[1]

Refined microsurgical techniques and advances in intraoperative monitoring of the cranial nerve function have improved surgical results in the elimination of this type of lesion. Mortality has diminished and the preservation of facial and cochlear nerves, with the consequent preservation of hearing, has become a reality. Nonetheless, the surgery of acoustic neuromas is risk-free and the possibility of serious post-surgical complications still exists.

The purpose of this review is to analyze the functional results obtained and the impairments due to surgery, which should be taken into account when patients are deciding and the personalized advice the surgeon should give in each case.

PATIENTS AND METHOD

Between November 1994, and September 2006, 120 patients with acoustic neuromas (2 of them with type 2 neurofibromatosis) were operated on in our department by the senior author (C.S.).

The patients were between 18 and 72 years of age (average, 50.8). The most prevalent age was in the 60's. The neuromas were on the right side in 58 patients and on the left in 64, out of a total of 52 men and 68 women.

The tumour size was classified as small if the greatest diameter of the lesion was <1.5 cm, medium if the diameter was between 1.5 and 3 cm, and large if >3 cm. Given this classification, we found 39 small schwannomas, 59 medium, and 22 large. Of the 39 tumours classified as small, 16 were intracannalicular (41%). Of all the lesions, 13 tumours were extracannalicular, 17 intracannalicular (1 of them >1.5 cm), and 90 mixed (intracannalicular and extracannalicular locations).

Of all the patients studied, 112 (93.3%) presented hypoacusia at the time of diagnosis; 84 (70%) had tinnitus, and 43 (35.8%) suffered episodes of vertigo.

The follow-up period of the patients ranged from 6 months to 12 years.

All the patients, before the operation, underwent tonal threshold and verbal audiometry. Evaluation of the facial nerve function was established through the House-Brackmann scale.

During the evaluation performed before surgery, vestibular tests were performed in 64 patients with videonystagmography, including a study of saccadic movement, cephalic agitation and positional nystagmus, and caloric tests.

Surgical Technique

The microsurgical location to approach the neuromas operated on was retrosigmoid in 75 cases, translabyrinthine in 44 cases, and transtemporal in 1. In 11 patients the placement of a preoperative ventricular drain was needed due to intracranial hypertension produced by tumours of >3 cm in diameter. Facial nerve function was monitored in all cases.

RESULTS

Tumour Control

The extent of the tumoural resection was classified as total, subtotal, or partial: 106 cases were classified as total resections, and in 14 it was necessary to leave a portion of the lesion (near-total resection); in 6 patients this was greater than 20% of the tumour size (subtotal resection) and patients were treated with radiosurgery in cases of growth. Of the 106 cases classified as total resection, the persistence of a minimal remnant was demonstrated in 13 by magnetic resonance images taken during follow-up, generally in the depths of the inner auditory canal when a retrosigmoid approach was used, but they did not evolve in any of the cases. Total resection of the lesion was performed in the 39 small neuromas, in 52 of the medium ones, and in 15 of the large ones. Thus, the removal of the entire tumoural volume was accomplished in 88.3% of the cases (Table 1).

Facial Nerve Preservation

Anatomical integrity of the facial nerve was conserved in 103 of the cases, which represents 85.8%. It was conserved in 38 (97.4%) of the small neuromas, 51 (86.4%) of the medium ones, and 14 (63.6%) of the large ones. In the long-term follow-up it was noted that 62 of them presented some facial nerve function, corresponding to degrees I and II according to the House-Brackmann classification, 26 of them showed degrees III or IV, and 7 had degrees V or VI (Table 2).

Of the 17 patients in whom facial nerves could not be anatomically conserved, a hypoglossal-facial anastomosis was performed in 16 of them. In 10 of the 16 patients on whom this procedure was performed, the final nerve function was degree III or IV. Finally, in 4 patients an gold weight implant was put in place in the upper eyelid to compensate

Table 1. Resection Extension

Extension of the Resection	*Small (<1.5 cm)*	*Medium (1.5-3 cm)*	*Large (>3 cm)*	*Total*
Total	39	52	15	106
Remainder	0	7	7	14

Table 2. Preservation of the Facial Nerve After Resection

Tumour Size	*Anatomical Preservation*	*House-Brackmann Degree After 6 Months*			
		1-2	*3-4*	*5-6*	Unknown
Small	38	27	11	0	0
Medium	51	29	11	5	6
Large	14	6	4	2	2

for the deficit in palpebral occlusion secondary to the facial palsy presented.

Of the 103 patients in whom the facial nerve was conserved intact, at the end of the surgical procedure the VII pair transmitted electrically in 90 of them with a greater or lesser intensity of electrical stimulation. Even so, in the immediate post-operative period only 30 of these 90 patients presented normal facial function; of the rest, in the immediate post-operative period, 27 patients presented paralysis of degrees V-VI, 17 degrees III-IV, and 16 degree II. In this regard, it is of interest to stress that a certain number of the cases of palsy were recorded a few days after surgery. At 6 months, 53 patients presented a normal facial exam. Thus, it can be affirmed that, despite conserving the VII pair intact and being functional at the end of the surgical procedure, only 33.3% maintained normal post-operative function, though at 6 months this function was normalized in 58.8% of patients.

Post-operative function of the facial nerve is relevant for patients' quality of life, as 10 of them suffered serious ocular problems caused by keratitis and corneal ulcers, resolved in 5 cases with conservative measures. The other 5 patients (4 of them with hypoglossal-facial anastomosis) required a gold weight implant in the upper eyelid to compensate for a deficit in palpebral occlusion secondary to poor facial function. Of these, 2 required a corneal transplant, one of them on 2 occasions.

Hearing Preservation

Anatomically, the cochlear nerve was preserved in 41% of the small tumours and in 8.47% of the medium ones, but function (classes 1 and 2 of the Gardner-Robertson classification) was preserved in just 54.5% of the small ones (Table 3). With respect to the final auditory status, we took into account how many patients post-operatively presented serviceable hearing and how many lost it as a consequence of surgery. Using grades 1 and 2 of the Gardner-Robertson classification as serviceable hearing, of our 120 patients, 43 presented a hearing of this type before operation, and of those, only 5 retained it post-surgically. The majority of those with valid hearing had medium and large tumours, so that in general terms the percentage of hearing conservation is much more modest than if only applied to small tumours.

The 2 patients with type-2 neurofibromatosis had bilateral tumours of more than 3 cm in diameter, and it was impossible to conserve hearing on another very deteriorated part. In both a hearing implant was placed in the brain stem on the occasion of the revision surgery, with an excellent result in one case and modest in the other. In the first of these, 40% discrimination was achieved in the vowel identification test with just the implant and 90% with the implant plus lip reading, while in the consonant identification test the percentages were 25% and 70% respectively, reaching 100% in short phrases with lip reading.

Post-Operative Complications

In the post-operative period, 2 patients (1.6%) died from a posterior fossa haemorrhage, involving tumours larger than 2.5 cm in diameter.

We divided the post-operative complications into early (when they occurred within the first week after surgery) and late (if they occurred in the second week). The most relevant early post-operative complications included 13 fistulae of cerebrospinal fluid (10.83%), 3 cases of meningitis (2.5%), and 4 strokes (3.3%). As late complications, we observed 2 fistulae of cerebrospinal fluid (1.6%) and 4 cases of meningitis (3.3%).

Among the 13 patients presenting fistulae of cerebrospinal fluid, 1 died due to a posterior fossa haemorrhage, 2 required surgical closure of the fistula, and in the rest they closed spontaneously (2), either by lumbar drainage (6), or ventricular drainage (2) placed during the operation.

Table 3. Hearing Preservation After Surgical Resection[a]

	Anatomical Preservation	*Pre-Operative Hearing*	*Post-Operative Hearing*	*Functional Preservation*
Small (39)	16 (41%)			
GR class 1		5	1	
GR class 2		6	5	
1+2		11	6	6/11 (54.5%)
Medium (59)	5 (8.47%)			
GR class 1		2	0	
GR class 2		3	0	
1+2		5	0	0/5 (0%)
Large (22)	0			
GR class 1		2	0	
GR class 2		3	0	
1+2		5	0	0/5 (0%)

[a]GR indicates Gardner-Robertson classification.

Post-Operative Vestibular Function

Without considering patients with mild impairments in vestibular compensation that manifested as a loss of spatial orientation or fleeting sensations of imbalance with turns of the head, which makes driving difficult or impossible, 9 patients (7.5%) presented an important permanent instability that translated into the inability to perform daily life activities or complete work activities, showing a variable degree of disability. In this group of patients a correlation with pre-operative vestibular function was not observed, and some had vestibular areflexia (3 cases), while others showed different degrees of vestibular dysfunction or normoreflexia.

DISCUSSION

Acoustic neuromas are diagnosed more frequently due to the development of new imaging technology, such as magnetic resonance; however, the actual incidence of symptomatic and asymptomatic vestibular schwannomas continues to be unknown, even though the current estimate is 1 in every 100 000 people each year.[2]

Our surgical results are compared to those of other published series as shown in Table 4.

For the treatment of this condition 3 possible options are considered, ranging from microsurgical resection to stereotactic or lineal accelerator radiosurgery or simply observation and follow-up of the patient with periodic audiometry and magnetic resonance, with the purpose of determining growth or inactivity of the lesion.

In our service we confront this type of surgery by 2 approaches: translabyrinthine and retrosigmoid. The choice of approach depends mainly on the size and position of the tumour and the possibility of conserving hearing in the ear operated on. In the most important series published, complete resection of the lesion is accomplished in 90%-98% of the cases.[3,4] Leaving a small portion together with the neural structure does not have serious repercussions in terms of the possibility of relapse, which is not the case in subtotal excisions (3% and 32% for Bloch et al[5]).

In various published series, facial nerve function is conserved in 65%-98% of patients.[4,6-10] Anatomical preservation does not mean functional normality as, even in centres with a lot of expertise, definitive facial function at degrees I-IV is attained in around 80% of the patients.[3,4] Optimal functional facial results (degrees I and II) 1 year after the operation depend greatly on the size of the tumour: they are the norm in small tumours, whereas in large tumours they generally do not go above 50%.[3,11]

The functional facial nerve results do not appear to be affected by the approach used; thus, in a series of 17 cases with an average size of 2.5 cm operated with the retrosigmoid approach, 59% of the patients had facial function of House-Brackmann degrees I-II after 1 year, while in 81 cases with an average size of 2.5 cm operated with the translabyrinthine method, 68% reached the same degree of facial function, without significant differences.[12]

It is difficult to predict post-operative facial function at the end of the operation, as there is no correlation between the potentials shown in the nerve through electrical stimulus and the presence or absence of palsy. In addition there is a possibility of facial paralysis appearing 5-30 days after the operation, which has been documented in 5%-25% of the patients, without any implication of age, size of tumour, neurophysiological parameters, or anatomical relations of the nerve with the tumour.[13,14] Approximately 80% of these patients recover normal facial function in less than 3 months, and the paralysis is attributed to a viral reactivation.[13]

The hearing preservation rate varies between 13% and 82%,[6-9,15-17] with a majority between 40%-50%, but there is some disagreement with respect to what constitutes valid hearing. The figures are biased, in that the calculation is established not on the totality of cases, but on a reduced group of tumours that by their size are deemed appropriate for the conservation of hearing. In this sense, it is very infrequent that hearing can be conserved with tumours >1.5-2 cm and in those that reach the depths of the inner auditory canal.

Additionally, the conservation of the cochlear nerve does not imply the retention of hearing, as a lesion in the internal auditory artery is a more frequent cause of hearing loss than

Table 4. Comparison of Our Results With the Series Published[a]

Author, Year	*Patients, No.*	*Mortality, %*	*Fistulae of CSF, %*	*Total Resection*	*Preservation of VII, %*
Coca, 2007	120	2 (1.6%)	12.5	88.3	85.8
Lee, 2001	162	1 (0.6%)	10.5	100 (S and M), 50 (G)	100 (S), 92.7 (M)
Jannetta, 1996	691	7 (1%)	17	83	94 (S), 88 (M), 75 (L)
Ojemann, 1992	410	2 (0.5%)	8	80	95-100 (S), 75 (M), 56 (L)
Ebersold, 1992	255	2 (0.8%)	11	97	92.6
Hardy, 1989	100	3 (3%)	31	97	82
Shiobara, 1988	125	2 (1.6%)	8.8	87	80
Glasscock, 1986	568	4 (0.7%)	14	99	94 (S), 92 (M), 55 (L)
Welch, 1985	77	4 (5%)	3.9	84	100 (S), 78 (M), 34 (L)

[a]L indicates large tumour size; CSF, cerebrospinal fluid; M, medium tumour size; S, small tumour size.

a lesion in the nerve itself. Of the 2 approaches used with the purpose of maintaining hearing (retrosigmoid and transtemporal), there do not appear to be, in general terms, any better results with either one.

According to Rigby et al, the greatest impact on the quality of life expressed by patients is hearing loss (61%), followed by balance alterations (14%), and facial paralysis (10%), with a worse evaluation of the latter in women than in men. Imbalance is present in 50%-85% of patients in the first few weeks after the procedure,[18-20] but after 2 years a disabling imbalance is only shown in around 10% of patients.[11]

This figure is in accordance with our experience, which does not mean that the rest of the patients do not have some limitations in certain aspects of daily life, as for example while driving. Thus, in a quality of life evaluation of 82 patients operated on for acoustic neuromas, Magliulo et al[21] observed that 23% had a variable degree of instability during walking that also affected work capacity in 20% of patients. In the same sense, Parving et al[22] state that 56% of patients still had dizziness 6 months after surgery, with alterations in work capacity in 26%. Impairments in the vestibular system tend to be more frequent in patients over 55 years of age, women, and those with pre-operative imbalance in the ENG.[23] On the other hand, a certain correlation has been observed between the pre-operative vestibular tests and the degree of post-operative imbalance, which is useful in alerting patients to the degree of post-operative dysfunction and initiating more aggressive methods of vestibular rehabilitation.[24]

In relation to the post-operative complications of neuroma surgery, fistulae are the most frequent. In the most recently published series, the rate of these fistulae varies between 2% and 10%,[4,25] and they are resolved in around 90% of cases with conservative measures or a lumbar drain.[26] The incidence of post-operative bacterial meningitis is between 2% and 5% in the published series and are normally associated with fistulae of cerebrospinal fluid.[25] In our study, there were 7 cases of meningitis (3 within the first week after surgery and 4 during the second week), representing 5.8% of the patients operated on. To avoid these complications, adequate closure of the dura mater is of the highest importance in the retrosigmoid method, and airtight covering of the surgical wound with abdominal fat in the case of a translabyrinthine approach. In both cases, external reinforcement of the closure with a biological adhesive may help reduce the rate of fistulae.

The post-operative mortality rate is between 0.5% and 1.5% and is generally due to post-surgical haemorrhage. Special attention should be paid to achieving perfect haemostasis prior to closure. It is also recommended to extubate the patient once the operation is finished, in order to detect any change in vital signs.

Another therapeutic area of interest in acoustic neuromas is stereotactic radiosurgery, the indication of which depends on various factors, such as size of the tumour (tumours <3 cm), age of the patient, contraindication for surgery, absence of symptoms, tumour in the only functioning ear, and patient preference. This procedure is elected by some patients as the rate of potential preservation of the facial nerve and hearing is greater, and the risks of surgery are avoided.[9,27-29] The rates of tumoural growth control in the long term have been estimated at between 86% and 95%,[9] even though in the case of progression of the tumour, the complications and surgical sequelae are greater. The most frequent complications with radiosurgery of acoustic neuromas are late and sometimes transitory cranial neuropathy, which developed between 1 and 21 months after treatment in 5%-36% of patients, including facial paralysis, while hearing is preserved in 75% of patients. In spite of all this, there continues to be a certain amount of controversy about radiosurgical treatment in the long run, since its mortality rate is lower than that observed in surgery, except with regard to facial and auditory function in tumours of <1 cm in centres with a lot of experience.[30]

Finally, in numerous cases one option to evaluate is conservative treatment through periodic controls with magnetic resonance and moving to more active measures in the case of an appreciable growth of the tumour. In 2 meta-analysis studies on a total of 2248 patients observed, progression was noted in 43%-51% of tumours, which showed growth of 1.9 mm/year, while the others remained stationary or reduced in size.[31,32] On follow-up, 51% had hearing loss,[32] falling below the level of useful hearing in one-third of the patients, which was at least comparable to the hearing preservation rate with small tumours.[31] On the other hand, 20% of patients required more active measures, either through surgery or radiotherapy, due to an appreciable growth in the tumour. Although there may be changes in the reference standards for the evolution of tumours in one way or another,[33] the growth rate over 1 year of follow-up is in many cases a factor predicting the eventual need for later treatment.[34] In addition, tumours arising in the cerebellopontine angle have a notably greater growth rate than intracannicular ones, which does not exclude the possibility of hearing loss in the absence of growth.[35] A wide variety of situations occur in patients with acoustic neuroma, so individualized treatment is required. Even for a single patient there may be different approaches that the subject should choose between, as surgery is not without complications and sequelae. There is a tendency to take the results from centres with a lot of expertise in this kind of surgery as standard practice, but extrapolation to most other hospitals would not be possible. At our department, the action protocol is as follows:

– Small and medium neuromas can be completely removed with anatomical preservation of the facial nerves, but hearing preservation is frequently not possible. In this group of tumours, regular check-ups or radiosurgery are 2 very valid options, above all in a certain group of patients, and should be evaluated

– In large tumours, the indication of surgery is much clearer, and total or near-total removal can be achieved along with anatomical preservation of facial nerves in most cases, even with temporary palsy

It is important to bear in mind, when considering treatment for this type of condition, the quality of life that our patients

will have after treatment, as there are some who present good pre-operative hearing but may lose it with surgical treatment. A small percentage show a permanent state of imbalance after surgery, which can be very disabling and can condemn the patient to a situation that will greatly affect their quality of life. The same occurs with facial aesthetics, with a not insignificant number of patients affected by transitory facial paralysis, and possible development in consequence of corneal alterations.

REFERENCES

1. Moukarbela R, Sabria A. Current management of head and neck schwannomas. Curr Opin Otolaryngol Head Neck Surg. 2005;13:117-22.
2. Lee S, Willcox T, Buchheit W. Current results of the surgical management of acoustic neuroma. Skull Base. 2002;12:189-95.
3. Lanman TH, Brackmann DE, Hitselberger WE, Subin B. Report of 190 consecutive cases of large acoustic tumors (vestibular schwannoma) removed via the translabyrinthine approach. J Neurosurg. 1999;90:617-23.
4. Samii M, Gerganov V, Samii A. Improved preservation of hearing and facial nerve function in vestibular schwannoma surgery via the retrosigmoid approach in a series of 200 patients. J Neurosurg. 2006;105:527-35.
5. Bloch DC, Oghalai JS, Jackler RK, Osofsky M, Pitts LH. The fate of the tumor remnant after less-than-complete acoustic neuroma resection. Otolaryngol Head Neck Surg. 2004;130:104-12.
6. Ojemann RG. Management of acoustic neuromas (vestibular schwannomas). Clin Neurosurg. 1993;40:498-535.
7. Samii M, Matthies C, Tatagiba M. Intracanalicular acoustic neurinomas. Neurosurgery. 1991;29:189-99.
8. Ebersold MJ, Harner SG, Beatty CW, Harper CM, Quast LM. Current results of the retrosigmoid approach to acoustic neuroma. J Nerosurg. 1992;76: 901-9.
9. Pollock BE, Lunsford LD, Kondziolka D, Flickinger JC, Bissonette DJ, Kelsey SF, et al. Outcome analysis of the acoustic neuroma management: A comparison of microsurgery and stereotactic radiosurgery. Neurosurgery. 1995;36:215-29.
10. Sampath P, Holliday MJ, Brem H, Niparko JK, Long DM. Facial nerve injury in acoustic neuroma (vestibular schwannoma) surgery: etiology and prevention. J Neurosurg. 1997;87:60-6.
11. Somers T, Offeciers FE, Schatteman I. Results of 100 vestibular schwannoma operations. Acta Otorhinolaryngol Belg. 2003;57:155-66.
12. Mamikoglu B, Esquivel CR, Wiet RJ. Comparison of facial nerve function results after translabyrinthine and retrosigmoid approach in medium-sized tumors. Arch Otolaryngol Head Neck Surg. 2003;129:429-31.
13. Magliulo G, d'Amico R, di Cello P. Delayed facial palsy after vestibular schwannoma resection: clinical data and prognosis. J Otolaryngol. 2003;32:400-4.
14. Grant GA, Rostomily RR, Kim DK, Mayberg MR, Farrell D, Avellino A, et al. Delayed facial palsy after resection of vestibular schwannoma. J Neurosurg. 2002;97:93-6.
15. Glassock ME III, Hays JW, Minor LB, Haynes DS, Carrasco VN. Preservation of hearing in surgery for acoustic neuromas. J Neurosurg. 1993;78:864-70.
16. Jannetta PJ, Moller AR, Moller MB. Technique of hearing preservation in small acoustic neuromas. Ann Surg. 1984;200:513-23.
17. Snyder WE, Pritz MB, Smith RR. Suboccipital resection of medial acoustic neuroma with hearing preservation. Surg Neurol. 1999;51:548-53.
18. Somers T, Offeciers FE, Schatteman I. Results of 100 vestibular schwannoma operations. Acta Otorhinolaryngol Belg. 2003;57:155-66.
19. Rigby PL, Shah SB, Jackler RK, Chung JH, Cooke DD. Acoustic neuroma surgery: outcome analysis of patient-perceived disability. Am J Otol. 1997;18:427-35.
20. Lynn SG, Driscoll CL, Harner SG, Beatty CW, Atkinson EJ. Assessment of dysequilibrium after acoustic neuroma removal. Am J Otol. 1999;20:484-94.
21. Magliulo G, Zardo F, Damico R, Varacalli S, Forino M. Acoustic neuroma: postoperative quality of life. J Otolaryngol. 2000;29:344-7.
22. Parving A, Tos M, Thomsen J, Müller H, Buchwald C. Some aspects of life quality after surgery for acoustic neuroma. Arch Otolaryngol Head Neck Surg. 1992;118:1061-4.
23. Driscoll CL, Lynn SG, Harner SG, Beatty CW, Atkinson EJ. Preoperative identification of patients at risk of developing persistent dysequilibrium after acoustic neuroma removal. Am J Otol. 1998;19:491-5.
24. El-Kashlan HK, Shepard NT, Arts HA, Telian SA. Disability from vestibular symptoms after acoustic neuroma resection. Am J Otol. 1998;19:104-11.
25. Weit RJ, Teixido M, Liang J. Complications in acoustic neuroma surgery. Otolaryngol Clin North Am. 1992;25:389-412.
26. Fishman AJ, Hoffman RA, Roland Jr T, Lebowitz RA, Cohen NL. Cerebroespinal fluid drainage in the management of CSF leak following acoustic neuroma surgery. Laryngoscope. 1996;106:1002-4.
27. Flickinger JC, Kondziolka D, Lunsford LD. Dose and diameter relationships for facial, trigeminal and acoustic neurophaties following acoustic neuroma radiosurgery. Radiother Oncol. 1996;41:215-19.
28. Niranjan A, Lunsford LD, Flickinger JC, Maitz A, Kondziolka D. Dose reduction improves hearing preservation rates after intracanalicular acoustic tumor radiosurgery. Neurosurgery. 1999;45:753-65.
29. Poen JC, Golby AJ, Forster KM, Martin DP, Chinn DM, Hancock SL, et al. Fractioned stereotactic radiosurgery and preservation of hearing in patients with vestibular schwannoma: A preliminary report. Neurosurgery. 1999;45:1299-307.
30. Meyer TA, Canty PA, Wilkinson EP, Hansen MR, Rubinstein JT, Gantz BJ. Small acoustic neuromas: surgical outcomes versus observation or radiation. Otol Neurotol. 2006;27:380-92.
31. Yamakami I, Uchino Y, Kobayashi E, Yamaura A. Conservative management, gamma-knife radiosurgery, and microsurgery for acoustic neurinomas: a systematic review of outcome and risk of three therapeutic options. Neurol Res. 2003;25:682-90.
32. Smouha EE, Yoo M, Mohr K, Davis RP. Conservative management of acoustic neuroma: a meta-analysis and proposed treatment algorithm. Laryngoscope. 2005;115:450-4.
33. Shin YJ, Fraysse B, Cognard C, Gafsi I, Charlet JP, Berges C, et al. Effectiveness of conservative management of acoustic neuromas. Am J Otol. 2000;21:857-62.
34. Deen HG, Ebersold MJ, Harner SG, Beatty CW, Marion MS, Wharen RE, et al. Conservative management of acoustic neuroma: an outcome study. Neurosurgery. 1996;39:260-4.
35. Walsh RM, Bath AP, Bance ML, Keller A, Tator CH, Rutka JA. The role of conservative management of vestibular schwannomas. Clin Otolaryngol Allied Sci. 2000;25:28-39.