

Acoustic Neuroma NIH 1991 Consensus Statement

ACOUSTIC NEUROMA

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ABSTRACT

The National Institutes of Health Consensus Development Conference on Acoustic Neuroma brought together neurosurgeons, radiosurgeons, otologists, neurologists, audiologists, otolaryngologists, and other health care professionals as well as the public to reach agreement (1) on defining the clinical types of acoustic neuroma, (2) on which procedures are useful for screening and diagnosis, (3) on the options available for managing the disorder as well as the complications of treatment, and (4) on the key clinical and biological areas for future research. Following 2 days of presentations by experts and discussion by the audience, a consensus panel weighed the evidence and prepared their consensus statement.

Among their findings, the panel concluded that (1) treatment for vestibular schwannoma must be individualized and requires an experienced, well-integrated, multidisciplinary team approach; (2) surgery remains the treatment of choice, but research is needed on the relative benefits and risks of all management options, including pharmaceutical and other

alternative medical treatments such as tumor suppressing agents; (3) routine intraoperative monitoring of the facial should be included in surgical therapy for vestibular schwannoma; (4) neurofibromatosis 2 (NF2) should be carefully considered in all patients newly diagnosed with vestibular schwannoma, and, when found, genetic evaluation and counseling should be provided for all relevant family members; and (5) a registry for all patients with vestibular schwannoma, whether undergoing observation or active management, should be established. The full text of the consensus panel's statement follows.

INTRODUCTION

The 1991 Consensus Development Conference on Acoustic Neuroma was convened to consider how patients can acquire an accurate diagnosis and to review the best options for management of this disease, including primary therapy, followup, and rehabilitation.

We use the term vestibular schwannomas throughout this report because these tumors are composed of Schwann cells and typically involve the vestibular rather than the acoustic division of the 8th cranial nerve. Although benign, because of their location vestibular schwannomas can produce serious morbidity or even death, by compression of vital structures, including the cranial nerves and the brainstem. Advances in microsurgery have dramatically reduced operative mortality and have made tumor removal without additional neurologic deficit a realistic but challenging goal.

An estimated 2,000 to 3,000 new cases of unilateral vestibular schwannoma

are diagnosed in the United States each year--an incidence of about 1 per 100,000 per year. The most common presenting symptoms are change in hearing in one ear, tinnitus (noise in the ear), and poor balance. The advent of MRI with gadolinium enhancement has permitted the identification of many very small, previously undetectable tumors. Some studies suggest that the prevalence of vestibular schwannomas at autopsy may be as high as 0.9 percent, but this is quite likely an overestimate. In any event, the vast majority of these tumors are very small and are not recognized clinically. At least 95 percent of diagnosed vestibular schwannomas are unilateral. These tumors are encapsulated, rounded, and usually appear as a single mass. About 5 percent of patients exhibit bilateral schwannomas associated with an inherited syndrome known as neurofibromatosis type 2 (NF2). Population-based data from the United Kingdom suggest that 1:35,000 individuals carry the gene for NF2.

Table 1 gives criteria that distinguish NF2 from NF1, which is a more common syndrome and rarely associated with vestibular schwannoma.

TABLE 1

NF1 may be diagnosed in Caucasians when two or more of the following are present:

- * Six or more cafe-au-lait macules whose greatest diameter is more than 5 mm in prepubescent patients and more than 15 mm in postpubescent patients.
- * Two or more neurofibromas of any type or one plexiform neurofibroma.

- * Freckling in the axillary or inguinal region.
- * A distinctive osseous lesion as sphenoid dysplasia or thinning of long-bone cortex, with or without pseudoarthrosis.
- * Optic glioma.
- * Two or more Lisch nodules (iris hamartomas).
- * A parent, sibling, or child with NF1 on the basis of the previous criteria.

NF2 may be diagnosed when one of the following is present:

- * Bilateral 8th nerve masses seen by MRI with gadolinium.
- * A parent, sibling, or child with NF2 and either unilateral 8th nerve mass or any one of the following:
 - * neurofibroma
 - * meningioma
 - * glioma
 - * schwannoma
 - * posterior capsular cataract or opacity at a young age.

WHAT ARE ACOUSTIC NEUROMAS AND HOW SHOULD THEY BE CLASSIFIED?

Cytologically, no differences have been found between the vestibular schwannomas of NF2 and those found in sporadic cases. Histologically, however, the tumors in NF2 often appear as grape-like clusters that can infiltrate the fibers of individual nerves and may adumbrate a polyclonal origin. Both unilateral and bilateral tumors vary in their precise location along the vestibular nerve, tending to arise at the border between the

central and peripheral segments of the nerve. Why tumors arise at this transition zone is not known, but variation in the site at which a tumor is located can have a major influence on the symptoms it produces.

For clinical management, the most useful classification of vestibular schwannomas is by size, location, and growth rate. However, tumors tend to enlarge unpredictably. Some do not change in size for many years, while others may grow at a rate of up to 20mm in diameter per year. Currently, the best method to monitor tumor growth is with gadolinium-enhanced MRI. To facilitate the interpretation of clinical studies, both the greatest diameter of the tumor within the posterior fossa and the extent of penetration into the intracanalicular space should be documented.

A second important classification is between familial and sporadic cases.

All cases of vestibular schwannomas are thought to result from the functional loss of a tumor-suppressor gene that has been localized to the long arm of chromosome 22. In at least 95 percent of patients, however, the disease is unilateral and the majority of these cases are sporadic, resulting from somatic mutations that are not associated with an increased risk for other tumors either in the individual or in close relatives. About 5 percent of patients exhibit bilateral disease or other features that define NF2. These patients are thought to carry a single germline mutation of the chromosome 22 linked gene and sustain the loss of the remaining normal allele as a somatic event in those cells that give rise to the tumor.

Thus, the trait is recessive at the cellular level but exhibits a dominant

pattern of genetic transmission in families. Even when a thorough family history is obtained, in about one half of all recognized cases of NF2, no evidence of other affected family members can be found. These may patients represent new germline mutations and are at risk of transmitting the disease to their offspring.

Patients with NF2 who carry new mutations tend to be more severely affected than familial cases, and some recent studies have raised the possibility that in familial cases the onset of symptoms may be earlier and the severity greater when the disease is inherited from the mother. Such effects can arise from genomic imprinting, and although the precise genetic mechanism for this phenomenon is unknown, a growing number of examples of such parental origin effects now have been documented. If confirmed, these findings could have practical implications for the management of families with NF2.

Molecular studies on NF2 and on unilateral tumors are at an exciting juncture. The gene for NF2 should soon be identified and may provide molecular explanations for clinical differences among families with NF2 as well as differences in the growth rate among tumors. Further studies on the molecular biology of the gene may suggest treatments for vestibular schwannomas, both in NF2 and in patients with unilateral diseases.

Patients with NF2 may have associated meningiomas and spinal root schwannomas as well as cafe-au-lait spots and peripheral Schwann cell tumors and often develop posterior subcapsular cataracts at an early age. The

prevalence of these findings varies greatly among families.

IN WHOM SHOULD ACOUSTIC NEUROMA BE SUSPECTED AND EVALUATED?

Sporadic Vestibular Schwannoma

The most common symptom, found in up to 90 percent of individuals with vestibular schwannoma, is a progressive, asymmetric, or unilateral sensorineural hearing loss. Approximately 70 percent have a high frequency pattern of loss, while a small number of patients will display either normal hearing or a symmetric hearing loss. A symptom sometimes reported, even in the face of apparently normal hearing, is distorted sound perception, often manifested as difficulty in using the telephone or perceiving instruments to be "off key" in one ear. Although most schwannoma-associated hearing loss is gradual and progressive, approximately 10 percent of patients report sudden loss of hearing. Less commonly reported symptoms in patients with vestibular schwannoma include unilateral or asymmetric tinnitus (ringing in the ears) with or without complaints of dizziness or disequilibrium. These symptoms are generally regarded as "early," but can be seen with both small and large tumors. It should be noted that only a small fraction of patients who suffer any one of the above symptoms will be found to have a vestibular schwannoma.

Other findings, generally regarded as "late" manifestations, are related to compressive effects of tumor mass on neighboring structures. These include headache, ataxia, cerebellar signs, and compressive cranial neuropathies.

The 5th cranial (trigeminal) nerve compression may cause facial pain and/or numbness and corneal insensitivity leading to ulceration. Compression or

irritation of the 7th (facial) cranial nerve may result in facial spasm, weakness, or paralysis. Infrequently, involvement of the 6th cranial nerve may cause double vision (diplopia). Compression of the 9th, 10th, or 12th cranial nerves will result in difficulty in swallowing and/or speaking. When the brainstem is sufficiently compressed or distorted by a large tumor, the patient may display nausea, vomiting, or lethargy, leading to coma, respiratory depression, and death. Hydrocephalus and papilledema with increased intracranial pressure also may be seen. With increasing tumor size and severity of symptoms, prompt diagnosis and initiation of treatment become vital.

Bilateral Neurofibromatosis (NF2)

NF2 is a complex syndrome in which many findings in addition to those described above may occur. These include:

- * Peripheral or central lenticular cataracts, which may be present even in very young children (80 percent of cases in one series).
- * Skin nodules and other lesions that include dermal neurofibromas and cafe-au-lait spots (greater than 60 percent of cases in one series).
- * Pain or numbness because of schwannomas of peripheral nerves and/or roots.
- * Seizures and other focal neurological symptoms.
- * Other findings related to meningiomas, which may be multiple, or to a variety of gliomas (astrocytomas, ependymomas, etc.).
- * Similarly affected relatives.

Once the diagnosis of NF2 is made, relatives who are at risk should be screened for the disease. NF2 should also be considered as a diagnostic possibility in patients with unilateral vestibular schwannomas who are under the age of 40.

How should patients be evaluated?

When vestibular schwannoma is suspected, the evaluation must begin with a thorough clinical and family history. This includes seeking the stigmata of NF2, schwannoma, or other nervous system tumors. The physical examination should focus on the skin and a neurological examination of cranial nerve function. Additional evaluation should include a detailed examination for cataracts and audiovestibular function.

The initial audiologic evaluation should include pure tone air and bone conduction thresholds, speech reception thresholds, and speech recognition (discrimination) scores. Beyond these tests, two other diagnostic approaches are commonly used. More sophisticated audiological tests such as the determination of acoustic reflex threshold, acoustic reflex decay tests, and brainstem auditory evoked responses (BAER, also termed ABR) may permit assessment of the site of the audiologic lesion. The other approach is gadolinium-enhanced MRI. The decision of which test to use depends on clinical judgement and level of suspicion. These are affected by family pedigree, degree of asymmetry of auditory symptoms, brainstem findings, or stigmata of NF2.

The advantages of BAER (ABR) are its ability to measure functional status

and its lower cost. Recent experience has shown that the sensitivity of BAER (ABR) is 94 percent and that the specificity is greater than 85 percent for the diagnosis of vestibular schwannoma. Auditory evoked responses, however, may not be possible in the face of severe hearing loss.

MRI now is regarded as the most definitive study that can be performed, and it is capable of revealing vestibular tumors as small as a few mm in diameter. This examination should emphasize thin slice scans in the axial plane with gadolinium enhancement. A negative gadolinium-enhanced MRI is accepted in current practice as effectively excluding the diagnosis of vestibular schwannoma. False positives are rare. A disincentive to the use of MRI as a screening test is its cost.

Vestibular testing is thought to be of less diagnostic value than the audiometric tests listed above, at least in part, because of the compensatory ability of the vestibular system.

Preoperative tests of vestibular function may be important as predictors of postoperative balance and possible hearing preservation at surgery.

Computerized axial tomography (CT) is useful in certain instances for screening purposes, particularly when MRI cannot be obtained. Some surgeons stress the usefulness of CT in preoperative planning.

WHAT ARE THE TREATMENT OPTIONS FOR THOSE WITH ACOUSTIC NEUROMA?

Currently, the ideal treatment for symptomatic patients with vestibular schwannoma is the total excision of the tumor in a single stage with minimal

morbidity and mortality and with preservation of neurological function. The other options for management are observation, subtotal removal, and various forms of radiation treatment, including stereotactic radiosurgery. Selection of the appropriate treatment option should be based on the clinical findings and status of the patient.

The question of whether and when to undertake treatment of a vestibular schwannoma is a complex issue. For the majority of patients who present with a symptomatic tumor, expeditious surgery will be the primary treatment modality. Young patients with progressive neurological deficit or evidence of tumor growth clearly are candidates for surgery. However, there are groups of patients for whom conservative approaches, including long-term observation, may be indicated. Elderly patients without severe neurologic symptoms or evidence of tumor growth are one such group. There also is evidence that some patients with unilateral vestibular schwannoma and a subgroup of patients with NF2 may have tumors that fail to progress rapidly, resulting in stable neurologic function for a long time. The use of MRI with contrast enhancement has resulted in the identification of patients with very small, relatively asymptomatic vestibular schwannomas for whom the natural history is still not known. Conservative management may be appropriate for these patients. The risk of neurologic deterioration in conservatively managed patients needs to be recognized and discussed with the patient.

Certain preoperative findings correlate with treatment outcome. When a

patient presents with a mild hearing loss and the preoperative ABR recording demonstrates normal results with well formed waves, the prognosis for hearing preservation after surgery is more favorable than when these conditions are not present. Conversely, when MRI shows a tumor that is larger than 2 cm or when the tumor fills the fundus of the internal auditory canal, the likelihood that useful hearing will be preserved is far lower. Expanding our understanding of how these and other preoperative findings correlate with treatment outcome should be a high priority for future research.

Advances in microsurgical technique, anesthesia, and perioperative care have significantly reduced the morbidity and mortality for vestibular schwannoma surgery and now permit total removal in a majority of cases. Excellent results have been reported for three major surgical approaches, each characterized by specific advantages and disadvantages. Hearing preservation should be a goal of surgery when tumor removal can be achieved without compromising the facial nerve. The middle fossa approach provides good extradural exposure for small lesions situated in the internal auditory canal and enables potential hearing preservation, especially for tumors arising from the superior vestibular nerve. This approach is less suitable for larger tumors with intracranial extension. The translabyrinthine approach sacrifices hearing but facilitates ventral exposure of small and large tumors and allows the surgeon to identify and protect the facial nerve. The suboccipital or retrosigmoid approach allows the surgeon to

identify the brainstem, cranial nerves, and cerebral vasculature through a wide exposure. In patients with small tumors, this approach facilitates hearing preservation. The approach also is suitable for large tumors. Criteria for the selection of surgical approach should be based on the training, experience, and preference of the surgical team; the status of preoperative hearing; and the location and size of the lesion.

There is a consensus that intraoperative real-time neurologic monitoring improves the surgical management of vestibular schwannoma, including the preservation of facial nerve function and possibly improved hearing preservation by the use of intraoperative auditory brainstem response monitoring. New approaches to monitoring acoustic nerve function may provide more rapid feedback to the surgeon, thus enhancing their usefulness.

Intraoperative monitoring of cranial nerves 5, 6, 9, 10, and 11 also has been described, but the full benefits of this monitoring remain to be determined.

In the majority of cases of vestibular schwannoma, the treatment goal is complete removal of the tumor with minimum morbidity and mortality. However, there are clinical situations where the more conservative goal of planned subtotal resection of the tumor may be indicated. Among these are patients requiring decompression in whom recurrence is unlikely because of limited life expectancy, and patients in whom hearing preservation is of importance because of diminished function of the contralateral ear.

The best published surgical outcomes in the treatment of vestibular

schwannoma are from medical centers that have highly organized and dedicated teams with a specific interest in these tumors and sufficient continuing experience to develop, refine, and maintain proficiency. Comprehensive surgical treatment of patients with vestibular schwannoma requires collaboration between health care providers from many disciplines, including neuro-otology, otorhinolaryngology, neurosurgery, anesthesiology, radiology, neurology, audiology, nursing, pathology, clinical neurophysiology, plastic surgery, ophthalmology, social service, and rehabilitation medicine, in addition to a strong institutional commitment and support for intensive care in the postoperative period. Teamwork is necessary for both planning and performing the primary surgical procedure and recognizing and managing potential intra- and postoperative complications.

Radiation therapy is a treatment option limited in current practice primarily to patients unable or unwilling to undergo otherwise indicated surgery. The greatest experience to date has been with stereotactic radiosurgery, using multisource Cobalt-60 units for single dose, external gamma ray therapy. Other options include conventional photon beam therapy and particle beam therapy, using either single or fractionated doses. Early reports indicate that retardation of tumor growth is observed in the majority of patients, but long-term followup from multiple centers is not yet available to fully assess therapeutic efficacy and complication rates.

Patient followup is an important component of management whether the primary treatment is surgery, radiation, or observation. The program for monitoring

patients includes obtaining a history of new findings, following the progression of known signs and symptoms, repeated neurologic examination, audiologic assessment, and radiographic imaging. Followup intervals may range from every 3 months initially to every 1 to 2 years, depending on the patient's clinical course. The interval between followup evaluations may be shorter initially and longer with the passage of time, if there is no evidence of recurrent disease or progression. The duration of patient followup may be lifelong, particularly in patients with NF2.

Management of bilateral vestibular schwannomas in patients with NF2 must take into account the risk of hearing impairment in both ears and the disabling consequences of acquired deafness. One side may progress more rapidly and dictate the need and priority of treatment. The previous loss of functional hearing in one ear raises additional management issues for treatment of the tumor on the side with better hearing. More conservative approaches, such as subtotal intracapsular resection or simple observation of the patient's progress, may be indicated.

Rational selection of specific treatment options is impeded by the absence of standardized terminology in the medical literature. In future reports audiometric assessment should be classified according to levels of residual hearing, with specific objective definitions for each level. Such categories might include mild, moderate, severe, and profound hearing loss, as determined by combinations of pure tone averages and speech recognition scores. Imaging of vestibular schwannomas by gadolinium-enhanced magnetic

resonance allows tumors to be classified according to volume and tumor location. Specific size categories should be developed to facilitate comparison of patient populations and treatment results. Facial nerve function should be reported according to a standardized grading scale, such as the House-Brackmann classification system. More sophisticated methods of assessing functional speech recognition and facial animation also may be useful in monitoring outcomes and evaluating management options. Patient age groups should also be standardized, with numerical definition of specific age groups. Studies suggest that three or more age groups may be useful.

WHAT ARE POSSIBLE ADVERSE CONSEQUENCES OF TREATMENT AND WHAT ARE THE

MANAGEMENT OPTIONS FOR EACH?

Both the vestibular schwannoma itself and its management can result in significant morbidity requiring intensive rehabilitative (and sometimes reconstructive) therapy. It is therefore vital that the health care team provide to patients and their families sufficient verbal and written materials so that they have realistic expectations of treatment outcomes.

When appropriate, referral to a former patient or peer support/information group can be most helpful.

The most serious perioperative complications occur in the first 72 hours. These include air embolism, intracranial hemorrhage, and stroke. Prompt recognition by the operative team can result in decreased mortality and morbidity. CSF leak and meningitis can occur in a delayed fashion and also require immediate therapy.

Loss of hearing in the operated ear is the most common adverse consequence and can be a serious handicap. These patients have difficulty hearing in even modestly noisy environments and do not have directional hearing. Young children are at an educational disadvantage. There are a number of devices that can be used to allow for partial compensation to make the acoustic signal louder than the background noise or bring sound from the impaired ear to the hearing ear. These devices can be used by both children and adults. Total loss of hearing occurs in many of the patients with NF2 and in a small number of patients with unilateral tumors who have had hearing loss in the nontumor ear from other causes. These are among the most seriously handicapped of all patients. There are a number of rehabilitation strategies that can be used to restore communication. Many of these are visually based, such as lipreading (speech), use of captions, sign language, etc. Sign language would be more useful if families were also instructed. Patients with visual defects, common in NF2, will have added difficulty in visual communication modes. Tactile systems are somewhat effective for the deaf-blind.

Electroprostheses are being developed and may be of potential benefit in selected patients with postlingual total deafness, secondary to loss of both statoacoustic nerves.

Abnormal vestibular function occurs in almost all patients. Unilateral loss for usual life situations has little morbidity and is compensated rapidly.

Vestibular dysfunction becomes significant when it is bilateral or occurs in

conjunction with other CNS or sensory impairment. Patients with bilateral vestibular dysfunction are at increased risk for drowning when swimming, diving, or even bathing.

One distressing complication of surgery is disfiguring facial nerve weakness or paralysis, with consequent physical, emotional, psychosocial, and possibly professional dysfunction. Treatment approaches to "re-animation" of the face include surgery (muscle or nerve grafting or re-routing) and physical and occupational therapy (exercise, biofeedback). As yet, none of these can restore normal function and appearance. Strong support from family, friends, the health care team, and patient advocacy/support groups is needed.

When complete closure of the eye is compromised, dryness, irritation, excessive tearing, blurred vision, corneal abrasions, ectropion, entropion, and loss of vision can occur. Surgical re-animation techniques can restore nearly normal function.

Other cranial nerves can be involved, but the particular combination of the 5th and 7th nerves places the cornea at greater risk and must be treated vigorously. The combined involvement of 9th, 10th, and 12th nerves creates difficulty swallowing and places the patient at risk for aspiration.

Headache may be a common and often debilitating complication of surgery. Its intensity can range from moderate to excruciatingly severe, and while most eventually resolve, they can last for months and sometimes years. Evaluation of the true incidence of postoperative headache, its etiology, and possible

treatment are needed.

Recurrence can occur in cases where tumors were apparently either totally or partially removed; thus all cases need to be followed by imaging. Those that have recurred may be managed by either re-operation or stereotactic or fractionated radiation. The results are modestly satisfactory for surgery, and marginally satisfactory for fractionated radiation therapy.

Complications of radiation occur late as opposed to the immediate complications of surgery. Stereotactic radiosurgery, a newer modality, has the benefit of a low early complication rate, but unknown long-term complications. The limited data available indicate that there is a high rate of hearing loss within 1 year after therapy. There may be delayed transient dysfunction of the 5th and 7th cranial nerves. Comparison of the complication rate with surgical techniques cannot be done until there are proper long-term data available. If surgery is required after radiation therapy, it may be more difficult and complication prone.

The emotional and interpersonal consequences of vestibular schwannoma on the patient and family must be anticipated. Appropriate and early intervention must be made by a team of professionals and must include advance preparation of the patient and family, emotional support, aggressive physical and rehabilitative therapy, and a carefully coordinated program of followup focusing on medical and psychosocial needs. The support team should consist of physicians, audiologists, nurses, social workers, physical and occupational therapists, and behavioral counselors.

Many complications would be deemed far less problematic--certainly less devastating--if patient needs and expectations were addressed preoperatively with precise knowledge of possibilities for their future. The patients should be educated to the degree that they understand the decision they must ultimately make and any potential consequences they will face in accordance with that decision. This may include referral to specialized facilities that deal with their particular problem. Complete and realistic written and audiovisual information should be presented at the time of diagnosis, hospitalization and operation, discharge, and at followup. Referral should be made to peer support groups and/or positive former patients early in the process.

Fear of the unknown exacerbates any threatening situation. The more knowledge imparted to patients, the more they participate in a decision, and the better they will be able to live with any possible after effects.

WHAT ARE APPROPRIATE AREAS FOR FUTURE RESEARCH?

Two recent advances--the development of gadolinium-enhanced MRI and the mapping of the gene for NF2--have opened major new areas of needed research.

The ability to diagnose vestibular schwannoma with unprecedented accuracy and to recognize much smaller tumors has enhanced dramatically the potential for the preservation of hearing. There is an urgent need for the development of protocols to collect carefully standardized pre- and postoperative data on unbiased patient samples so that the influence of relevant variables on treatment outcomes can be objectively assessed.

The establishment of an international vestibular schwannoma registry also could yield valuable epidemiological and demographic data on the distribution of the disease. This could provide the basis for studies of diagnostic method, treatment and rehabilitative modalities, and complication rates, and for case control studies of possible environmental factors that might influence tumor development.

Now that the chromosomal location of the NF2 gene has been determined, its successful cloning can be anticipated in the near future. This achievement may provide immediate insight into the pathogenesis of the disease, the extent of the genetic heterogeneity that exists among families, and the cause for the associated findings in NF2. These studies would be greatly facilitated by the establishment of a cell repository and tissue bank.

There also is an urgent need for careful longitudinal studies of families with NF2 to document the natural history of the disease. Little is known about the control of schwann cell growth in humans and the factors that may contribute to formation of vestibular schwannomas. Research to define the specific factors that control growth could have important therapeutic implications. For example, evidence suggests that angiogenic factors may play a role in tumor growth and their pharmacologic inhibition could provide an exciting approach to treatment of this disease. The evidence that hormones influence the growth of schwannomas is inconclusive. Because the target is so small, vestibular schwannoma conceivably could become a candidate for somatic gene therapy. Other approaches to the control of tumor

growth by the manipulation of specific growth factors would be greatly enhanced by the availability of cells from schwannomas and from normal human nerves to study the growth of schwann cells in vitro. Finally, the cloning of the gene for NF2 could ultimately lead to the development of animal models of the disease in transgenic mice.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- * There are a variety of treatment options for vestibular schwannoma, including observation, surgery, and radiotherapy. Treatment must be individualized and requires an experienced, well-integrated, multidisciplinary team approach. For the majority of symptomatic patients with vestibular schwannoma, surgery remains the treatment of choice. There is a need for research into the relative benefits and risks of all management options, including the development of pharmaceutical and other alternative medical treatments, such as tumor suppressing agents.
- * MRI has revolutionized the diagnosis of vestibular schwannoma, allowing the identification of previously undetectable lesions. The natural history and optimal strategy for managing these patients have not yet been determined.
- * The benefits of routine intraoperative monitoring of the facial nerve have been clearly established. This technique should be included in surgical therapy for vestibular schwannoma. Routine monitoring of other

cranial nerves should be considered.

* There is an urgent need for clarification and standardization of the nomenclature and parameters used to describe the tumor and its clinical manifestations. A collaborative interspecialty effort should be organized to address this issue.

* NF2 should be carefully considered in all newly diagnosed patients with vestibular schwannoma, and when found, genetic evaluation and counseling should be provided for all relevant family members.

* There is a need for an expanded program of public and professional education to achieve earlier diagnosis.

* There is a need for expansion of support groups and early rehabilitation for patients with vestibular schwannoma.

* The imminent cloning of the NF2 gene on chromosome 22q will undoubtedly shed light on the molecular mechanisms underlying vestibular schwannoma formation and will open many new avenues for research and possible therapy.

Recommendations

* Future activities and research efforts should include:

* establishment of a registry for all patients with vestibular schwannoma, including those undergoing observation rather than active management; - descriptive and analytic epidemiologic studies targeting potential environmental causes of vestibular schwannoma;

* development of a tissue repository and greater use of cell cultures and

animal models for studies of the factors that influence tumor growth; -
refinement of surgical techniques with a focus on lowering morbidity;
* improved communication between health care providers, patient advocate
groups, and patients about diagnosis, treatment options, prognosis,
side effects, and available support;
* improved documentation of long-term outcome in relation to treatment
modality;
* increased research on and reimbursement for rehabilitation, including
hearing deficits, facial nerve dysfunction, eye disorders, and the
psychological impact of vestibular schwannoma.

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