Pediatric Audiologic Profile in Type 1 and Type 2 Neurofibromatosis

Anita T. Pikus*

Abstract

The neurofibromatoses with two subclasses known as NF1 and NF2 are two genetically distinct, autosomal dominantly inherited conditions with significant ramifications in the human auditory system. NF1 is a multisystem progressive disorder that can frequently involve portions of the auditory system in diverse and subtle ways and in which no characteristic audiologic findings can be discerned. NF2 is characterized by the presence of bilateral vestibular schwannomas, sometimes associated with multiple intracranial and spinal tumors. In 43 children with NF1, significant auditory system involvement was found by pure-tone, immittance, and auditory brainstem response (ABR) evaluation. Indications are that audiologists need to contribute to the diagnosis and management in this condition. In 13 children with NF2, handicapping hearing loss was not the primary or usual presenting symptom. However, current findings suggest that ABR and acoustic reflex studies are always indicated in the pediatric NF2 population and are as valid and significant as in adults with NF2.

Key Words: Auditory brainstem response (ABR) abnormalities, auditory system involvement, bilateral vestibular schwannomas, hearing loss, pediatric audiologic profile, pediatric NF1, pediatric NF2, pediatric neurofibromatoses, type 1 neurofibromatosis, type 2 neurofibromatosis

The fascination with the conditions now known as the neurofibromatoses or neurofibromatosis 1 and neurofibromatosis 2 (NF1 and NF2) is an ancient one. There is evidence of interest extending as far back as the 13th century where, in a monastery manuscript, a man with NF1-like stigmata is described (Mulvihill, 1990). In the 1700s, a medical student, Tilesius, described a "wart man" who also demonstrated spots of irregular form, macrocephaly, and scoliosis (Mulvihill, 1990). Approximately 100 years ago, Frederich Daniel Von Recklinhausen used the term neurofibroma or fibroneuroma in discussing patients he studied with this disorder (Warkany, 1981). Then there was Dr. Frederick Treves's experience in England in the early part of this century with a patient called "the elephant man," about whom a play and a film were recently produced. In reality, the young man, Joseph Merrick, was rescued by Dr. Treves and became the darling of Victorian English high society (Rubenstein et al, 1981). Although it is now believed that Merrick had Proteus syndrome, rather than NF1, his condition and the recent dramatizations of his life have given impetus to the study of NF1. It is now thought that Wishart treated a patient with NF2 in his 1822 article describing a man with multiple intracranial lesions and bilateral acoustic tumors (Mulvihill, 1990; Baldwin, 1991). The intervening years until NF1 was identified genetically were replete with a confusing array of names and descriptors for both of these conditions. Even more noteworthy is the fact that many clinicians and researchers considered NF1 and NF2 to be a single disease entity (Mulvihill, 1990) until the gene marker for NF1 was identified on chromosome 17 in 1987 (Barker et al, 1987). From the perspective of clinical hearing science, it is pertinent that investigation of auditory system function was not systematically addressed in NF1 even as late as 1987 by the medical community (Neurofibromatosis Consensus Statement, 1988). In the case of NF2, the study of auditory system function was not considered separately from auditory system results in spo-
radic unilateral acoustic neuroma (Pikus et al, 1982; Pikus, 1990). In fact, most literature in audiology still does not recognize the need to evaluate and investigate NF2 separately from sporadic unilateral acoustic tumor (SUAT), even though we have known for some years that the etiology, the anatomy and physiology, the treatment, and the prognosis of NF2 and SUAT are distinctly different (Musiek, 1992; Robinette, 1992). There has been some literature on acoustic tumors in children but with little data on auditory function (Hernanz-Schulman, 1986). Investigation of either of the neurofibromatoses in childhood has been sporadically addressed but without a systematic study of the auditory system (Pensak et al, 1989; Pikus, 1990; Miyamoto et al, 1991).

### TYPE 1 NEUROFIBROMATOSIS IN CHILDREN

NF1 is known to be a common, autosomal-dominant disease, occurring at the rate of approximately 1 in 3000 live births in the United States (Mulvihill, 1990). Thus, NF1 is actually more common in the general population than many of the more widely known inherited neurologic diseases (Pikus et al, 1981). This has been demonstrated repeatedly and is now well known in the epidemiologic community and among various groups of investigators (see Table 1). This relatively common occurrence of NF1 has not yet been widely appreciated in clinical practice or by the general public. Indeed, many health institutions and/or government agencies still consider it a rare disease.

NF1 usually manifests in early childhood with increasing stigmata associated with increasing age. Table 2 provides the most up-to-date diagnostic criteria established for NF1 (Martuza, 1992). Note that it does not yet include the genetic marker for the disease as identified on the centromosome of chromosome 17 (Barker et al, 1987). Although some pigmented lesions (cafe-au-lait spots) are usually present at birth or soon after (Riccardi, 1981), it is known that puberty and pregnancy are usually associated with increased growth of neurofibromas and the development of other symptomatology in many organ systems (Bolande, 1981; Rubinstein et al, 1981). The variability and severity of phenotypic expression from birth through adulthood are not predictable from affected members within the kindred or on the basis of the current molecular genetics. This holds true for auditory changes as well. Auditory system anomalies found in our initial 32 patients (10 males and 22 females) did not correspond to the physician’s rating of the severity of each patient’s disease (Pikus et al, 1981).

### Table 1 Occurrence of NF1 in the General Population (U.S.) as Compared to Other Known Inherited Disorders

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Approximate No. U.S. Cases*</th>
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<tbody>
<tr>
<td>NF1</td>
<td>75,000</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
<td>30,000</td>
</tr>
<tr>
<td>Sickle cell anemia</td>
<td>20,000</td>
</tr>
<tr>
<td>Huntington's</td>
<td>17,500</td>
</tr>
<tr>
<td>Duchenne's muscular dystrophy</td>
<td>15,000</td>
</tr>
</tbody>
</table>

*1992 data obtained from personal communication with disease foundations.

### Method

Since obtaining data on those initial 32 patients with NF1 (not limited to children), we can now report on audiologic data obtained from a total of 43 children from age 5 through age 20 years. These include standard data points from conventional behavioral studies of pure-tone and speech thresholds, suprathreshold studies of speech recognition and tolerance, biomechanical studies of middle ear function, and electrophysiologic investigation using auditory brainstem response (ABR). Twenty-two males and 21 females are included for the routine audiologic battery, and 33 affected individuals (17 males and 16 females) completed ABR. All studies were accomplished in sound-isolated testing suites using standard, commercially available, calibrated equipment. In all cases, only traditional audiologic techniques were

### Table 2 Diagnostic Criteria for NF1*

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

*From Martuza, 1992 and NIH Consensus Conference on Acoustic Neuroma, Program and abstracts.
employed, and sedation was not used for any study. No patient with active or no history of chronic ear disease, ototoxic history, or noise-induced hearing loss was included.

These patients have come to Clinical Audiology from various studies across institutes at the National Institutes of Health in Bethesda, Maryland and, thus, may not represent the most typical sample of children with neurofibromatosis.

**Results**

Of the 43 members of the group (21 females, 22 males), only four females and three males (16%) had audiologic results that could be considered completely within normal limits. This does not compare well with estimates of hearing sensitivity and auditory function for this age group throughout the general population. Pure-tone hearing was abnormal (poorer than 20 dB) in 10 females (48%) and 14 males (64%) (see Table 3). Handicapping hearing loss was found in only six patients (five males and one female), and of those, one male had bilateral handicapping involvement. There is no singular audiometric configuration seen characteristically in these patients and the likelihood of progressive or fluctuating hearing loss cannot be ruled out. Tympanometry was found to be abnormal (hyper- or hypomobile in 10 patients (4 females and 6 males). As these patients did not have middle ear effusion or any other identifiable middle ear condition, the etiologic bases of the middle ear anomalies causing changes in otoimmittance and/or compliance were unclear. In the original study of affected NF1 patients ranging in age from 5 to 61 years, 21 of 32 patients revealed abnormal middle ear function (Pikus et al, 1981). Thus, although still far beyond chance- or population-based estimates, this pediatric cohort shows fewer measurable middle ear anomalies than did the initial study (Table 3).

Acoustic reflex (AR) results in this group of children were found to be abnormal in 9 of 22 males and 10 of 21 females for a total of 19 of 43 children with NF1. These abnormalities were thought not to be due strictly to biomechanics in the middle ear, but rather, in most cases, to neurologic changes. In 6 of the 19 patients with abnormal ARs, tympanometry and acoustic reflex results were abnormal in the same individual. Of those six, one had peaked and notched tympanograms with AR responses appropriate to one completely deaf ear; another revealed hypomobile middle ear systems bilaterally (with normal pressure peaks) and excellent normal hearing but absent and elevated ARs and abnormal ABRs. Still another had normal tympanometry but elevated and absent ARs with abnormal ABRs. This patient was found to have optic glioma and precocious puberty. A fourth patient demonstrated extremely hypermobile tympanograms (multiply notched without history of tympanic membrane perforation or ossicular disarticulation) and elevated ARs while another child revealed hypomobile middle ear systems and abnormal ABRs. The sixth child showed aberrant middle ear findings on the basis of a large neck mass (neurofibroma).

ABR studies were completed on 33 NF1 children. Results in this population revealed that 16 of the 33 children (49%) showed abnormalities, usually prolongations of the I–V interpeak interval or absent wave V. Other results, such as reversed V/I wave amplitude ratios or prolonged wave V only in the rapid click rate stimulus condition, were considered “soft signs” and not included in these data as abnormal. Consistent with what is known of NF1, none of these individuals had acoustic neuroma. However, eight of these patients had known intercranial lesions

<table>
<thead>
<tr>
<th>Patients</th>
<th>Pure Tone (%)</th>
<th>Tympanometry (%)</th>
<th>Acoustic Reflex (%)</th>
<th>ABR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>11 (48)</td>
<td>17 (39)</td>
<td>11 (48)</td>
<td>11 (31)</td>
</tr>
<tr>
<td>Abnormal</td>
<td>10 (48)</td>
<td>4 (19)</td>
<td>10 (48)</td>
<td>5 (31)</td>
</tr>
<tr>
<td>Males†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>8 (36)</td>
<td>16 (37)</td>
<td>13 (52)</td>
<td>6 (27)</td>
</tr>
<tr>
<td>Abnormal</td>
<td>14 (64)</td>
<td>6 (27)</td>
<td>9 (41)</td>
<td>11 (65)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Normal</td>
<td>19 (44)</td>
<td>33 (77)</td>
<td>24 (56)</td>
<td>17 (52)</td>
</tr>
<tr>
<td>Abnormal</td>
<td>24 (56)</td>
<td>10 (23)</td>
<td>19 (44)</td>
<td>16 (48)</td>
</tr>
</tbody>
</table>

*Female mean age = 10.8 years; range = 5-20 years; †male mean age = 11.4 years; range = 6-9 years.
including optic glioma, hypothalamic hamartoma, astrocytoma, and other tumor formation within the brain. Other investigators have also found children with NF1 demonstrating ABR abnormalities (Pensak et al, 1989), some with poor or uncertain correlation to magnetic resonance imaging (MRI) or other clinical findings (Duffner et al, 1989).

All results for pure-tone findings, tympanometry, AR findings, and ABRs were found to be significant in terms of abnormalities of auditory function as compared to normals (p > .001 for males and females). Results of speech threshold or recognition studies were not significant in this population.

Discussion

These results reflect a diversity of anomalies in the auditory system antithetical to the development of any hallmark or typical findings specific to NF1, a finding much like NF1's effects in other organ systems. Nevertheless, evidence to date demonstrates that the auditory system in NF1 patients is, like most other organ systems in the body, clearly at risk and requires evaluation at regular intervals. As NF1 is a disorder involving both neuroectodermal and mesodermal tissues and results in multiple changes over time throughout various organ systems, these auditory system findings are consistent with what is already known about the course of the disease and expand our understanding of its dimensions. We know that NF1 people are at increased risk for neurologic disorders including seizures, mental retardation, and learning disabilities (Eldrige et al, 1989). We know that they are at increased risk for visual system anomalies including lisch nodules, optic glioma, and compromised vision (Kaiser-Kupfer et al, 1989). Certainly, the skeletal system is notoriously affected in NF1, with scoliosis and other bony problems commonly documented. We also know that NF1 individuals are at increased risk for developing neoplastic conditions, including various cancers (Hope and Mulvihill, 1981). In consideration of these and other widespread effects of NF1 throughout various organ systems, it would seem odd that the auditory system could be isolated and totally free from the effects of this multisystem, progressive, genetic disorder. These data suggest that the opposite is true and that hearing and auditory system function are, indeed, at risk in NF1 and warrant evaluation and monitoring at regular intervals in patients with NF1. Certainly, in order to adequately and accurately evaluate any child for learning disabilities, which are found with greater frequency among children with NF1 (Eldridge et al, 1989), the integrity of the auditory system must be assessed. In addition, on the basis of this and earlier studies, it would be appropriate to include ABR evaluation in the serial audiologic studies established to follow children with NF1 (Pikus, 1990).

TYPE 2 NEUROFIBROMATOSIS IN CHILDREN

NF2 is a dominantly inherited tumor syndrome characterized by bilateral vestibular schwannoma but without the other, more visible stigmata to the degree associated with NF1. In addition, NF2 is now known to have a completely different gene locus from NF1. The marker for NF2 was first identified in 1987 (Rouleau et al, 1987) on the long arm of chromosome 22. Frequently, other intercranial and spinal tumors as well as posterior capsular lens opacities have been identified in young adults (Kaiser-Kupfer et al, 1989; Eldridge et al, 1990). The hearing loss classically associated with SUAT is not usually an early sign in NF2 (Pikus, 1990). There are currently no population-based estimates of the prevalence of NF2, but data from a recent medically based survey in a midwestern state suggest approximately 5000 cases of NF2 in the United States (Eldridge and Parry, 1992). The most current suggested diagnostic criteria established for NF2 are listed in Table 4.

According to recent data, when studies of multigenerational families with NF2 are clustered by the presence or absence of other tumors of the central nervous system and age at onset, three major subsets or types of NF2 emerge. They are (1) Feiling and Gardner type, having few other central nervous system tumors and slow progression; (2) Wishart group, which includes other brain tumors, spinal tumors, and a moderately rapid disease pattern; and (3) the

<table>
<thead>
<tr>
<th>Table 4 Diagnostic Criteria for NF2*</th>
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<tr>
<td>NF2 may be diagnosed when one of the following is present:</td>
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<tr>
<td>Bilateral VIIIth nerve masses seen by MRI with gadolinium.</td>
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<tr>
<td>A parent, sibling, or child with NF2 and either unilateral VIIIth nerve mass or any two of the following:</td>
</tr>
<tr>
<td>Either neurofibroma, meningioma, glioma, or schwannoma.</td>
</tr>
<tr>
<td>Posterior capsular cataract or opacity at a young age.</td>
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</table>
Lee and Abbott type, with multiple associated brain and spinal tumors and a rapid course with early morbidity (Eldridge and Parry, 1992). According to this work, hearing loss and sudden deafness occur latest in the life span among those individuals falling within the Feiling and Gardner subset; usually, it is not documented until the third or fourth decade of life (Eldridge and Parry, 1992).

In looking specifically at pediatric NF2, one would expect to see fewer numbers of patients under age 20, and those who would present for study or management could be expected to represent the more severe forms. Our earliest data set on a small group of patients with NF2 included all ages, resulting in a mean age of 28 years (Pikus et al, 1982). At that time, most other clinicians and investigators were considering NF1 and NF2 to be variants of the same disorder or were combining audiologic findings in NF2 with those resulting from SUAT.

**Method**

For this study, the patient population selected was limited to those known to be affected with NF2 (as documented by MRI) and seen for evaluation in our facility before their 21st birthday. That group includes seven males (average age: 16) and six females (average age: 15). Audiologic results on the group of children comprising at-risk but unconfirmed NF2 will not be discussed here. A more detailed analysis of audiologic findings in the at-risk population in NF2 is available in the recent literature (Pikus, 1990).

All 13 patients were evaluated by means of behavioral studies of pure-tone and speech thresholds, suprathreshold speech recognition and tolerance under earphones, biomechanical techniques of assessing middle ear integrity (tymanometry and acoustic reflex brainstem neural arc evaluation), and ABR using a conventional earlobe-vertex montage. As in the NF1 group, all testing was accomplished using sound-isolated testing suites and standardized, commercially available equipment. Because of the time span these data represent, and because of the age of many of the subjects, vestibular assessments were either not available at the time of evaluation or were not accomplished in patients under 12. No patients were included with active ear disease, history of noise exposure, or treatment with ototoxic agents. Earlier in our studies of NF2 patients and at-risk family members, several special psychoacoustic tests were used but later discarded when no significant data could be extracted from their use. Our experiences from an earlier pilot study (Pikus et al, 1982) found that masking level difference studies and various special tests of speech recognition/perception had minimal diagnostic utility in this population.

**Results**

Of these 13 patients, three individuals (one 19-year-old male and two females, ages 17 and 16) demonstrated entirely normal peripheral pure-tone sensitivity (Figure 1, A). It is interesting to note that all three are thought to belong to the milder Feiling and Gardner form of NF2. It is relevant to highlight the very subtle or mild sensitivity changes that can exist early in the course of NF2 (Figure 1, B). Comparing Figure 1, A and B, one sees the slight pure-tone abnormalities in children early in the course of this condition. The finding that 77 percent of this small cohort demonstrates poorer than normal pure-tone thresholds is clearly significant. In a recent study of 20 affected individuals ranging in age from 10 to 72 years, with mean age more than twice that of this pediatric cohort, it was found that 90 percent demonstrated pure-tone abnormalities (Pikus, 1990). This slight difference is likely to be a result of the difference in age and in the size of the group studied. Specific audiometric configuration in pediatric NF2 may not be significant except for the likelihood that one or more frequencies above 1000 Hz will be involved in the early stages, if only very mildly. Results of speech thresholds or studies of speech recognition were found to be noncontributory in this population for diagnostic purposes in all but one affected individual.

Tympanometry in this group of patients was uniformly normal. AR results were found to be abnormal in 10 of the 13 subjects (all of the females and four males, as seen in Table 5). Thus, 77 percent of this pediatric population demonstrates the classic AR findings associated with adult acoustic neuroma of any type in almost the same proportion as reported in the literature (Linthicum and Brackman, 1980; Jerger, 1983; Robinette et al, 1992). Most investigators have found that about 85 percent of adult patients studied with acoustic neuroma of any type show various manifestations of abnormal AR function. The abnormalities of AR function are not specific to NF2 and are seen vari-
Figure 1  Sample pure-tone hearing in pediatric NF2. A, Normal pure-tone threshold sensitivity in three children with NF2. B, Typical mild abnormalities of pure-tone threshold changes seen in pediatric NF2. Open circles = right ear, crosses = left ear.

usaha as elevated, absent, or decaying responses with no significant differences among the types of aberrant function. Eventually, all AR activity disappears, either by virtue of disease progression or on the basis of iatrogenic effects.

ABR results in this pediatric population also mirror the adult NF2 population. This group of seven males and six females all had abnormal ABR results, with the exception of one young woman, whose ABR was still normal (at age 20) in terms of absolute and interpeak interval between waves I and V (Table 5). We were able to obtain vestibular studies on this individual, and, indeed, electronystagmography results were markedly abnormal. Thus, 12 of 13 subjects had abnormal ABR (92%), but all 13 had at least one of the classic, electrophysiologic abnormalities associated with the neu-

Table 5  Summary of Audiologic Findings in 13 Patients with Pediatric NF2

<table>
<thead>
<tr>
<th>Patients</th>
<th>Pure Tone (%) (n = 13)</th>
<th>Acoustic Reflex (%) (n = 13)</th>
<th>ABR (%) (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric cohort</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(age range: 10–20 yrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td>3 (13)</td>
<td>3 (13)</td>
<td>1 (8)</td>
</tr>
<tr>
<td>Normal</td>
<td>10 (77)</td>
<td>10 (77)</td>
<td>12 (92)</td>
</tr>
<tr>
<td>Full cohort*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(age range: 10–72 yrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td>18 (90)</td>
<td>17 (85)</td>
<td>20 (100)</td>
</tr>
<tr>
<td>Normal</td>
<td>2 (10)</td>
<td>3 (15)</td>
<td>0</td>
</tr>
</tbody>
</table>

*From Pikus, 1990.
rologic perturbations of space-occupying lesions in the ascending auditory nervous system. In a previously published study of 20 affected individuals between ages 10 and 72, all 20 had abnormal ABR (Pikus, 1990). The combination of the larger N weighted with predominantly adult patients in that study population would explain the slight (but not significant) differences between those ABR results and the current ones.

Discussion

The pure-tone deficits in children and young adults undergoing evaluation for NF2 are frequently so mild as to be ignored or, if noted, explained on the basis of artifact, patient compliance, or mild pure-tone threshold changes due to noise exposure (see Figure 1, B). Results of pure-tone findings in this study are consistent with recent opinion that increasing hearing loss is partially associated with increasing age but not necessarily with the size of the tumor. Figure 2 shows the MRI, pure-tone audiogram, and ABR of a 22-year-old with minimal, fairly symmetric, pure-tone deficit and monstrous tumor on the right. The left tumor was, itself, of significant proportions (2 cm), but its impact paled in comparison to the growth on the right (5.5 cm). The ABR is particularly ominous with completely absent later waves bilaterally. Here again, handicapping hearing loss was not present in this youth even with severe NF2. In an earlier study not limited to children, the presence of peripheral pure-tone sensitivity deficit (hearing poorer than 20 dB) was highly significant in both affected individuals and in identifying at-risk first-degree family members (Pikus, 1990). If increasing age is a factor in increasing diversity, complexity, and measurability of auditory deficits, then it is not surprising that this pediatric population would have fewer and milder peripheral auditory deficits. However, in an at-risk population, pure-tone abnormalities, even subtle ones (without other known causes), are suspect and must raise the level of concern. Those at-risk are currently defined as:

- A parent, sibling, or offspring of an affected person.
- A youth or young adult with mild skin findings of NF1 but not meeting the criteria for NF1.
- A person under 30 years of age with unilateral acoustic neuroma.
- A child or youth with a meningioma or schwannoma.
- A person with multiple nervous system tumors not explained by another disorder (Martuza and Eldridge, 1988; Parry and Eldridge, 1992).

The most important concept pertinent to the early diagnosis and adequate audiological management of NF2 children is to understand the responsibility to proceed to the full battery of biomechanical and electrophysiologic studies of auditory function regardless of the presence or absence of symptoms.

![Figure 2 MRI shows bilateral vestibular schwannomas of dramatically different proportions. The auditory brainstem response shown here is severely abnormal. The audiogram shows minimal, symmetric, pure-tone deficit. Open circles and A.D. = right ear; crosses and A.S. = left ear.](image-url)
of handicapping hearing loss or even mild auditory threshold changes. Even in the absence of tinnitus or subjective auditory system complaints, one must proceed to these studies. Indeed, these objective studies must be conducted on all at-risk children, or we are not providing current standard of care. We cannot rely on the old concepts of reduced speech recognition or asymmetric hearing loss as prerequisites or justification to go to ABR and AR studies in this population. Those were requirements that grew out of experience with SUAT, a separate condition from NF2 that is now well documented to have different causes, manifestations, treatment priorities, and outcomes. AR and ABR results in this pediatric NF2 population have proven to be powerful tools in the screening for early identification and in clinical corroboration of the presence of NF2. Certainly, until diagnosis can be made by DNA marker (and NF2 cannot yet be diagnosed by DNA in most families), these studies are essential in the diagnostic process. Even after modern genetic techniques become the diagnostic gold standard, electrophysiologic studies and behavioral tests of auditory function will be necessary to various aspects of patient care management in NF2. Audiologic expertise will be required for input into development and implementation of intraoperative, medical, audiologic, and psychosocial strategies for optimum patient care. Audiology in NF2 becomes increasingly relevant in the present, cost-conscious health care environment because auditory system evaluation is inexpensive as well as risk free, noninvasive, fast, and highly reliable.

Recently, investigators have shown otoacoustic emissions to be useful in assessing peripheral auditory system function in adults with acoustic tumor both pre- and postoperatively (Robinette, 1992). Although it was not specified whether or not NF2 patients were included in investigations of otoacoustic emissions in acoustic tumor, these data are relevant in NF2. Our work (currently under way) in establishing normative data in various patient populations is also beginning to reveal the value of otoacoustic emissions in NF2. For children with NF2, it is probably safe to say that otoacoustic emissions will soon be added to the audiologist's armamentarium of objective studies for use in the diagnostic process as well as in assessing outcomes and developing management strategies.

**CONCLUSION**

F1 and NF2 are two separate and distinct autosomal dominant disorders that have very little in common in terms of underlying molecular genetics, phenotypic presentation, or diagnostic criteria. However, for the audiologist, they have several critical components in common. These can best be considered as they impinge on our professional training, clinical management, and clinical research activities.

Unfortunately, most audiologists have little experience addressing the very basic issues of how genetic disorders can affect hearing and auditory system function (when deafness is not the primary symptom). Furthermore, audiologists are not usually trained to understand the various possibilities of auditory system involvement when structure or function is anomalous in neurologic, musculoskeletal, metabolic, or other systems. Many known genetic diseases for which gene markers or actual gene loci have been discovered are likely to have auditory system components needing further study and definition. Our understanding of the role of audiology in defining and describing various diseases must expand to fill this growing need. Although the gene markers for NF1 and NF2 have been identified, scientists and clinicians do not know how to predict the severity or extent of these diseases nor the speed or pattern of their progress. Intimate knowledge of the auditory system changes — what they are and when they happen — in both of these conditions may be pertinent in effective and cost-conscious diagnosis and management of these diseases. In addition, it is possible that auditory system measures may be pertinent in calibrating or assessing certain treatment regimens. Certainly, the accelerating pace of progress in molecular genetics will increasingly require that audiologists expand and improve their knowledge base and that they be prepared to take more professional initiative.

Evidence from this and other studies (Pikus, 1991; Higgins et al, 1992) suggests that the auditory system is rich in measurable responses to subtle changes in various systemic substrates represented throughout the structure and function of the auditory system. It is a worthy and challenging part of our purview to discover and document those changes and determine how they relate to the neurofibromatoses.

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REFERENCES


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