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Auditory Dysfunction in Selected Syndromes and Patterns of Malformations: Review and Case Findings

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Abstract

Hundreds of syndromes may be associated with hearing impairment. Within recent years, there has been heightened research and clinical interest in hearing and syndromes, probably due to both advances in molecular genetics and improved techniques for auditory assessment of infants and young children. An example of the current appreciation for the possible relation between auditory dysfunction and syndromes or patterns of malformations is the inclusion of syndromes as a risk factor for hearing impairment by the 1990 Joint Committee on Infant Hearing. In this paper, we review syndromes and patterns of malformation that are frequently or occasionally associated with hearing impairment. In addition, we illustrate, in case studies, auditory findings that may be associated with three of these syndromes and patterns of malformation: Carpenter syndrome, ichthyosiform dermatosis, and Townes syndrome. We conclude with a discussion of strategies for audiologic assessment and management of infants and children with syndromes and patterns of malformations.

Key Words: Antley-Bixler syndrome, auditory brainstem response (ABR), Carpenter syndrome, Cornelia de Lange syndrome, hearing, Hollermann-Streiff syndrome, itchyosiform dermatosis, malformation, otopalatodigital syndrome type II, syndromes, Towne syndrome, VATER syndrome

Within recent years, an increasing number of papers have described auditory dysfunction associated with unusual syndromes (e.g., Skinner, 1981; Egelund, 1987; Marres et al, 1989; Morris et al, 1991; Northern and Downs, 1991; Bess and Hall, 1992; Hall and Denneny, 1993). The heightened research and clinical interest in the topic is probably due to both advances in molecular genetics and improved techniques for auditory assessment of infants and young children, such as aural immittance measures, the auditory brainstem response (ABR), and otoacoustic emissions (OAEs). Current appreciation for the possible relation between auditory dysfunction and syndromes or patterns of malformations is perhaps best illustrated by passages from the Joint Committee on Infant Hearing 1990 Position Statement (Joint Committee on Infant Hearing, 1991). The committee includes among neonates (birth to 28 days) and infants (29 days to 2 years) at risk for hearing impairment those with "craniofacial anomalies including morphologic abnormalities of the pinna and ear canal, absent philtrum, low hairline, etc." and "stigmata or other findings associated with a syndrome known to include sensorineural hearing loss (e.g., Waardenburg or Usher's Syndrome" (Joint Committee on Infant Hearing, 1991, p. 15).

The identification of and intervention for auditory dysfunction in infants and children with syndromes or patterns of malformation can be especially challenging for at least five reasons. First, a cursory understanding of embryology and medical genetics and pertinent

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terminology is, minimally, essential. Second, there are hundreds of syndromes and patterns of malformation that may have auditory dysfunction as a feature. Unfortunately, the auditory findings associated with the majority of these syndromes and patterns of malformation are not thoroughly described in the literature. Third, the type and degree of auditory dysfunction may vary substantially, ranging from conductive hearing impairment due to middle ear pathology or malformation to sensory (cochlear) dysfunction, to central nervous system (CNS) dysfunction, or a combination of these types, and ranging from mild to profound in severity. Fourth, the hearing impairment may not be static but, rather, progressive in its development and/or delayed in its onset. Finally, because children with syndromes or patterns of malformations suspected of hearing impairment often have multiple sensory and motor deficits and CNS involvement, they may be extremely difficult to test with conventional behavioral audiometric techniques.

In this paper, we review syndromes and patterns of malformation that are frequently or occasionally associated with hearing impairment. This review is by no means exhaustive. Our intention is to provide the clinical audiologist with an introduction to the complexities of syndromes affecting the auditory system and a handy source of pertinent information on the topic, which is not always readily available. Then, we illustrate with case studies auditory findings that may be associated with three of these syndromes. We conclude with a discussion of strategies for audiologic assessment and management of infants and children with syndromes and patterns of malformations. Definitions of important terms, including, for example, the distinction among a syndrome, an association, a sequence, and a pattern of malformation; the difference between malformation, deformation, and disruption; and the difference between hereditary and congenital hearing impairment are presented elsewhere in this issue.

SELECTED SYNDROMES AND PATTERNS OF MALFORMATIONS

Hundreds of syndromes and patterns of malformations may have auditory dysfunction as a component. Some syndromes or patterns of malformations that are either frequently or occasionally associated with hearing impairment are listed in Table 1. (These syndromes and patterns of malformation are arranged alphabetically to facilitate quick access to the information.) The listings, and the information included for each entity, are by no means exhaustive. More detailed descriptions of the auditory and other, more general, findings summarized in these tables can be found in two comprehensive textbooks on syndromes and patterns of malformation (Jones, 1988; Gorlin et al, 1990). We summarize the information, however, with the presumption that many clinical audiologists will not have direct access to the original sources and may desire ready access to information on whether auditory dysfunction is a feature for syndromic children undergoing hearing assessment.

Unfortunately, the published clinical reports of auditory findings for many of the syndromes are often rather limited, particularly when they predate current audiometric techniques. In some papers, auditory dysfunction is simply described as "deafness." Without doubt, auditory dysfunction documented for thousands of other children with syndromes has gone unreported. Measurement of auditory status in children, including infants, using current behavioral and electrophysiologic techniques would certainly contribute to more detailed description of the type, degree, and time course of hearing impairment in syndromes and also presumably result in a higher estimation of the prevalence of hearing impairment in syndromes in general.

In Table 2, we summarize physical findings, auditory findings, and the management strategy for eight children evaluated within the past year by the Audiology Clinics at the Vanderbilt University Medical Center. Data for each of the eight children augment the simple description of findings for these syndromes displayed in Table 1. Children with three of these syndromes (Hollermann-Streiff, otopalatodigital type II, and VATER) are less than 2 years of age. Diagnostic audiologic assessment for these three infants is still in progress, and test results are not yet complete. Auditory findings associated with one of the other syndromes (Cornelia de Lange) have recently been reported in some detail in the literature (Egelund, 1987; Marres et al, 1989). Our Cornelia de Lange patient had the expected conductive hearing loss, which was successfully managed medically and surgically. The purpose of the presentation of the findings in Table 2 is to highlight patterns of auditory findings that may be encountered with these syndromes but have not to our knowledge been reported in the literature. It is clear from inspection of Table 2 that conductive hearing loss is a common component of syndromic auditory dys-

Table 1 Alphabetical Listing of Selected Syndromes Associated with Auditory Dysfunction*

Syndrome	*Category of Syndrome*	*Ear Malformation*	*Auditory Dysfunction*
Abruzzo-Erickson (cleft palate, eye coloboma, short stature, hypospadias)	Orofacial clefting	Soft, prominent pinnae	MHL, SNHL
Acrodysostosis	Skeletal dysplasia	Otitis media (recurrent ear infections)	CHL
Acrocraniofacial dystosis	Craniosynostosis	Dysplastic ears	MHL
Acrofacial dysostosis (Reynolds syndrome)	Head and neck	—	MHL
Antley-Bixler	Craniosynostosis	Dysplastic ears, low-set protruding ears, EAC atresia	CHL
Apert (acrocephalosyndactyly)	Head and neck	Low-set ears, otitis media, congenital ossicular (stapes) fixation	CHL†
Auro-digital-anal	Craniosynostosis	—	SNHL†
Baller-Gerold	Craniosynostosis	Dysplastic ears, low-set ears	CHL
Beckwith-Weidemann	Overgrowth syndrome	Ear lobe grooves, indented ear lesions on helix or concha	CHL
Branchio-oto-renal	Branchial arch	Preauricular or helical pits, various forms of abnormal pinnae, narrow or atretic EAC, fused ossicles, inner ear malformations	CHL, SHL, MHL†
Campomelic	Chondrodysplasia	Otitis media	CHL
Camurati-Englemann	Connective tissue	—	MHL
Carpenter	Craniosynostosis	Low-set ears, preauricular pits	CHL, SHL, MHL
Cerebro-costo-mandibular	Miscellaneous	—	SNHL?
Cervico-oculo-acoustic (Wildervanck)	Branchial arch	Preauricular tags, malformed pinnae, atretic EAC, ossicular abnormalities, inner ear and vestibular abnormalities	CHL, SNHL, MHL†
CHARGE (association)	Miscellaneous association	E = ear anomalies; ear may be small, cup-shaped, lop-shaped	CHL, SHL, MHL†
CHILD	Limb defect	—	SNHL?
Cleft lip sequence	Facial defects	Middle ear dysfunction (otitis media)	CHL†
Cleft palate syndromes	Orofacial clefting	Large ears, otitis media, ossicular fixation	CHL†
Cleidocranial dystosis	Osteochondrodysplasia	Middle ear dysfunction (incomplete mastoid air cell development)	CHL
Cornelia de Lange (Brachmann de Lange)	Small stature	Low-set ears	SNHL†
Crouzon	Craniosynostosis	EAC atresia, otitis media (cleft palate)	CHL

Table 1 (Cont'd) Alphabetical Listing of Selected Syndromes Associated with Auditory Dysfunction*

Syndrome	*Category of Syndrome*	*Ear Malformation*	*Auditory Dysfunction*
Cockayne	Senile-like appearance	—	SNHL
Craniodiaphyseal dysplasia	Craniotubular disorder	—	MHL†
Craniometaphyseal dysplasia	Osteochondroplasia	—	SNHL, CNS
del 18q	Chromosomal abnormality	Prominent antihelix & antitragus, narrow or atretic EAC	CHL
Diastrophic dysplasia	Osteochondrodysplasia	EAC stenosis, ossicular fixation, otitis media (cleft palate)	CHL†
Dyskeratosis congenita	Hemartoses	—	SNHL?
Ectrodactyly-ectodermal dysplasia-clefting	Facial-limb defects	Small or malformed auricles, middle ear dysfunction (secondary to cleft palate), ossicular malformation	CHL, SNHL
Facio-audio-symphalangism	—	—	CHL†‡
Facio-auriculo-radial dysplasia	—	Dysplastic pinnae	CHL
Fanconi pancytopenia	Limb defects	Auricular anomaly	SNHL?
Fetal iodine deficiency effects	Environmental agents	—	SNHL, CNS†
Fetal methyl mercury effects	Environmental agents	—	SHL†
Fetal trimethadione effects	Environmental agent	Poorly developed, cupped, or overlapping helix	CHL, SNHL?
FG	Facial-limb defects	Small, simple ears	SNHL, CNS
Fibrodysplasia ossificans progressiva	Connective tissue disorder	—	SNHL?
Fountain	Unusual facies	—	SNHL†
Fraser (cryptophthalmos)	Head and neck	Malformed pinnae, otitis media, stenotic EAC, ossicular defects	CHL
Frontometaphyseal dysplasia	Osteochondroplasia	—	MHL, SNHL†‡
Goldenhar	Facial-auriculo-vertebral spectrum (1st and 2nd branchial arch syndrome	Microtia, preauricular tags and/or pits, middle ear dysfunction	CHL, SHL, MHL†
Goltz-Gorlin (focal dermal hypoplasia)	Skin disorder	—	MHL†
Hajdu-Cheney (acroosteolysis)	Bone disorder	—	CHL, SNHL†
Hay-Wells syndrome of ectodermal dysplasia	Facial-limb defects	Cup-shaped ears, EAC atresia, middle ear dysfunction	CHL

Table 1 (Cont'd) Alphabetical Listing of Selected Syndromes Associated with Auditory Dysfunction*

Syndrome	*Category of Syndrome*	*Ear Malformation*	*Auditory Dysfunction*
Hunter (mucopolysaccaridosis II)	Storage disorder	—	SHL or MHL†‡
Hurler-Scheie compound (mucopolysaccaridosis I H/S)	Storage disorders	Otitis media	CHL, MHL
Hyperphosphatasemia	Bone disorder	—	USHL
Hypotelorism-microtia-clefting (Bixler)		Hypoplastic pinnae and EAC, atretic EAC, ossicular abnormalities	CHL
Johanson-Blizzard	Small stature	—	SNHL†
Kartagener	Miscellaneous sequences	Middle ear dysfunction secondary to mastoiditis	CHL†
Keutel	Miscellaneous	Diffuse calcification of pinnae cartilage	MHL
KID syndrome	Skin disorder	K = keratosis, I = ichthyosis, D = deafness	SNHL†
Killian/Teschler-Nicole (tetrasomy 12p)	Chromosomal abnormality	Large ears with protruding lobules, stenosis of EAC	CHL, SNHL, MHL
Klippel-Feil sequence	Miscellaneous	—	CHL, SHL†
Kniest dysplasia (metatropic dysplasia, type II)	Skeletal disorder	Otitis media	CHL, SHL†
LADD syndrome	L = lacrimo, A = auriculo, D = dento, D = digital	Cup-shaped pinnae	SNHL
Lenz-Majewski	Bone disorder	—	SNHL†
LEOPARD syndrome (multiple lentigines syndrome)	L = lentigines, E = electro-cardiographic abnormalities, O = ocular hypertelorism, P = pulmonic stenosis, A = abnormal genitalia, R = retardation of growth, D = deafness		SNHL†
Levy-Hollister	Lacrimo-auriculo-dento-digital syndrome	Small, cup-shaped ears; short helix	MHL, SNHL†
Mannosidosis (II)	Storage disorder	—	SNL†
Marshall	Facial defects	—	SHL†
Maxillofacial dysostosis, X-linked	Craniofacial defects	Prominant pinnae	MHL†
McCune-Albright	Hemartoses (small spots or tumors)	Narrowing of IAC	NHL
Melnick-Fraser	Branchial arch anomalies	Preauricular pits, malformed middle/inner ear	CHL, SHL, MHL†

Table 1 (Cont'd) Alphabetical Listing of Selected Syndromes Associated with Auditory Dysfunction*

Syndrome	*Category of Syndrome*	*Ear Malformation*	*Auditory Dysfunction*
Metaphyseal chondroplasia, Jansen type	Osteochondrodysplasia	—	SNHL?
Miller (postaxial acrofacial dysostosis)	Facial-limb defects	Hypoplastic, cup-shaped ears (syndrome resembles Nager and Treacher Collins)	CHL
Mohr	Facial-limb defects	Middle ear (ossicular) malformation	CHL†
Morateaux-Lamy (mucopolysaccharidosis VI)	Storage disorder	Upper respiratory tract infections with otitis media	MHL, SHL†
Morquio (mucopolysaccharidosis IV)	Storage disorder	Upper respiratory tract infections with otitis media	MHL, SHL†
Multiple lentigines	Hamartoses (many tumors)	LEOPARD is an acronym, D = deafness, prominent ears	SHL†
Multiple synostosis (symphalangism)	Skeletal dysplasia	Fusion of middle ear ossicles (staples fixation)	CHL†
Murcs association	Miscellaneous	External ear defects	CHL, SHL
Nager	Facial-limb defects	Preauricular tags, aural atresia	CHL, MHL†
Neurofibromatosis II		—	NHL (bilateral)
Noonan	Moderate small stature	Low-set and/or abnormal auricles	SHL, NHL†
Oculodentodigital (oculodentodigital dysplastia) type 1 (Lobstein disease)	Facial-limb defects	—	CHL
Oral-facial-digital	—	Low-set ears	CHL
Otodental	Head and neck	—	SHL†‡
Oto-palato-digital, type I (Taybi syndrome)	Facial-limb defects	Cleft palate with middle ear dysfunction	CHL†
Osteopetrosis (Albers-Schonberg disease)	Bone disorder	—	USHL
Osteopetrosis (benign autosomal dominant Type I)	Bone disorder	—	CHL
Oto-palato-digital, types I and II	Facial-limb defects	Low-set ears, middle ear dysfunction (cleft palate)	CHL
Pallister-Killian (mosaic tetrasomy 12p)	Chromosomal abnormality	Fleshy pinnae	USHL
Postaxial acrofacial dysostosis (Miller syndrome, Wildervanck-Smith syndrome, Genee-Wiedemann syndrome)		Cleft palate, cup-shaped pinnae, malformed EAC and middle ear	CHL
Progeria (Hutchinson-Gilford)	Senile-like appearance	Middle ear dysfunction (ossicular fixation)	CHL, SHL, CNS

Table 1 (Cont'd) Alphabetical Listing of Selected Syndromes Associated with Auditory Dysfunction*

Syndrome	*Category of Syndrome*	*Ear Malformation*	*Auditory Dysfunction*
Rieger	Miscellaneous	—	CHL
Robin sequence (Pierre Robin syndrome)	Facial defects	Middle ear dysfunction	CHL
Saethre-Chotzen	Craniosynostosis	Prominent ear crus, small ears, otitis media	CHL, SNHL
Sialidosis	Storage disorder	—	USHL
Sanfillippo (mucopoly-saccharidosis III)	Storage disorder	—	USHL
Scheie (mucopoly-saccharidosis I S)	Storage disorder	—	SNHL?
Sclerotosis	Osteochondroplasia	Narrowing of IAC	NHL
Senter (ichthyosiform erythroderma)	Ectodermal dysplasia	Excessive EAC skin debris	SNH†
Shprintzen	Facial-limb defects	Minor auricular abnormalities, cleft palate (eustachian tube)	CHL†
Stickler	Facial-limb defects	Middle ear dysfunction (cleft palate)	CHL, SNHL, MHL†
Townes (Townes-Brock)	Facial-limb defects	Large ears, poorly formed ears, or microtia; preauricular tags (resembles VATER syndrome and facio-auriculo-vertebral sequence)	SNHL
Treacher Collins	Mandibulofacial dysostosis	Malformed auricles, EAC defect, aural atresia/microtia	CHL, MHL†
Trisomy 13	Chromosomal abnormality	Abnormal helices, low-set ears	SNHL
Trisomy 14	Chromosomal abnormality	Preauricular tags or pits, occasional EAC atresia	CHL
Trisomy 8	Chromosomal abnormality	Prominent cup-shaped ears with thick helices	CHL
Van Buchem disease	Bone disorder	—	SNHL, MHL‡
VATER association	Miscellaneous	—	SNHL
Velocardiofacial (Shprintzen, Selackova)	Head and neck	Small auricles, thickened helices, otitis media (cleft palate)	CHL
Waardenburg [types I,II])	Facial defects		SHL†
XO (Turner)	Chromosomal abnormality	Prominent and protruding auricles	SNHL†

*Compiled from Jones, 1988; Gorlin et al, 1990.
†Hearing loss is often a prominent feature of the syndrome.
‡Progressive hearing loss.
CHL = conductive hearing loss, SHL = sensory hearing loss, SNHL = sensorineural hearing loss, USHL = unspecified hearing loss, NHL = VIIIth cranial nerve involvement, MHL = mixed hearing loss, CNS = central nervous system involvement.

Table 2 Summary of the Characteristics and Management of Selected Children with Syndromes and Malformations at the Vanderbilt University Medical Center

Syndrome	*Patient Age/Gender*	*Physical Findings*	*Auditory Findings*	*Audiologic/Otologic Management Strategy*
Antley-Bixler	2 yrs, female	Midface hypoplasia, choanal atresia, upper airway obstruction, recurrent otitis media, developmental delay, cardiac arrest, spine and limb deformities, vaginal atresia	Type B tympanograms; SF SAT at 80 dB HL, no response to pure tones in sound field, IMP: profound mixed hearing impairment	Tracheotomy, antibiotics, myringotomy and tympanostomy tubes, full ABR with sedation
Carpenter's	6 mo, female	Syndactyly, kidney deformity, recurrent otitis media, very small external ear canals	Type B tympanograms, moderate-severe CHL by ABR before and after PE tubes, IMP: persistent significant CHL, possible ossicular chain malformation	Antibiotics, bilateral myringotomies and tympanostomies, hearing aid use
Cornelia de Lange	1.5 yrs, female	Bilateral otitis media	Type B tympanograms, SF SAT and pure-tone responses at 80 dB HL moderate-severe CHL* by ABR pre-PE tubes, IMP: normal hearing sensitivity post-PE tubes	Myringotomy and tympanostomy tubes, antibiotics, monitor hearing with behavioral and immittance testing
Hollermann-Streiff	1.5 yrs, female	Cataracts, microphthalmia, short stature, developmental, delay, small ears, hypoplastic nasal cartilage ("pinched nose"), hypotrichosis	Mild hearing impairment by pure-tone and speech audiometry in SF, IMP: possible mild SNHL in better ear	Full ABR with sedation for ear-specific findings
Otopalatodigital	2 mo, male	Low-set ears, micrognathia, cleft palate, bowing of long bones, overlapping digits	Delayed ABR absolute latencies and 40- to 50-dB ABR thresholds, IMP: moderate apparent CHL	Repeat ABR with bone conduction, otologic consult, amplification if indicated
Senter (ichthyosis)	4 mo	Low-set ears; deformed ear lobes; peeling, cracking, and scaly skin; flattened nose	Normal minimal responses for speech and tonal signals, after removal of skin debris from EAC, ABR within normal limits, IMP: normal peripheral and brainstem auditory function	Periodic removal of skin debris from EAC
Towne	5 yrs, female	Chronic otitis media, small pinna with cupped-shape helix, small stature, single kidney, imperforated anus digital deformities	Delayed ABR absolute latencies and 50- to 60-dB air-conduction thresholds, 40-dB bone-conduction ABR thresholds, bilateral mixed loss (40 dB right and 60 dB left) by pure-tone audiometry, IMP: moderate mixed hearing loss	Myringotomy, tympanostomy tubes, amplification

Full ABR = auditory brainstem response with air- and bone-conduction and tone-burst stimulation, as indicated; SF = sound field; SAT = speech awareness threshold; IMP = impressions.
CHL = conductive hearing loss; SHL = sensory hearing loss; SNHL = sensorineural hearing loss; NHL = VIIIth cranial nerve involvement; MHL = mixed hearing loss; CNS = central nervous system involvement.

function and that application of the cross-check principle (Jerger and Hayes, 1976) is important for adequately describing auditory status in this challenging pediatric population.

We present next case reports illustrating with greater detail auditory findings, including behavioral tests, immittance measures, and ABR, for three unusual syndromes that are listed in Table 1: Carpenter, ichthyosis dermatosis, and Townes. For each of the three syndromes, there are very few published reports describing auditory status, and these studies are almost exclusively limited to a description of pure-tone audiometry findings. We discuss the auditory findings for each case in the context of this literature.

CASE REPORTS

Case 1: Carpenter Syndrome

Background. The characteristics of Carpenter syndrome (acrocephalopolysyndactyly type II) were first reported in 1901 (Carpenter, 1901), but the syndrome wasn't clearly identified until over 60 years later (Temtamy, 1966). Carpenter syndrome is an autosomal-recessive inherited disorder. Even now, however, literature delineating the history and physical findings associated with Carpenter syndrome is scarce. Children with the syndrome are of normal size at birth. The major features are craniofacial anomalies, such as craniosynostosis, digital abnormalities (polydactyly and syndactyly), and short stature. These features contribute to the likelihood of eustachian tube dysfunction and recurring middle ear disease with conductive hearing loss. Oral and dental abnormalities contribute to speech disorders. Auricles may be low set and preauricular pits may be present. Children with Carpenter syndrome may also have sensorineural auditory dysfunction and mixed hearing loss (Robinson et al, 1985). Below-average intelligence is sometimes a feature of the syndrome. Other important physical findings include preaxial polydactyly of feet and bony abnormalities of the limbs.

Clinical Findings. The patient was a 5-month-old girl with multiple congenital abnormalities who was referred to a pediatric otolaryngologist by her pediatrician for recurrent otitis media. She weighed 2159 grams at birth (37 weeks' gestation). She presented to the otolaryngology and audiology clinics with a history of multiple congenital anomalies, including hypoplastic kidneys, microcephaly and syndactaly (of the third and fourth digits of all extremities), musculoskeletal anomalies, retinal dysplasia of the right eye, and gastroesophageal reflux. Growth and development were delayed. Otologic examination showed that her auricles were deformed (lop of superior helix) and her external ear canals were extremely narrow, preventing a complete view of the tympanic membranes. There was evidence of otitis media with effusion bilaterally. The patient was initially treated with antibiotics and referred for audiologic assessment.

ABR under sedation (chloral hydrate) yielded a reliable response bilaterally, but absolute latencies (waves I, III, and V) were markedly delayed and responses were consistent with moderate-to-severe hearing impairment, greater for the left ear than the right ear. Latency-intensity functions are illustrated in Figure 1. Bone-conduction stimulation ABR was attempted but could not be completed before the patient awoke. A return visit in 2 months for behavioral audiometry, and ABR if necessary, was recommended. Middle ear disease did not respond to antibiotics, and the patient underwent bilateral myringotomies with placement of tym-

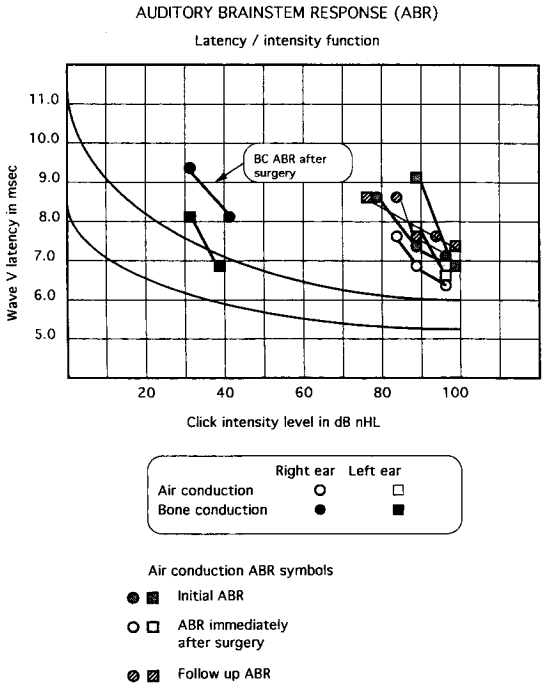

Figure 1 Serial ABR latency-intensity functions for a 5-month-old girl with Carpenter syndrome. ABR findings for air- and bone-conduction stimulation are shown for assessments before, immediately after, and 2 months after myringotomy with placement of ventilation tubes. ABR consistently confirmed severe bilateral conductive hearing loss.

panostomy tubes 3 months after the initial ABR assessment (at 8 months of age). Microscopic visualization of the ears showed very narrow ear canals (3 mm at the narrowest point and bilateral middle ear effusions). A thick, glue-like substance was aspirated from each ear before the tubes were placed.

ABR was repeated immediately after surgery while the patient was under general anesthesia. With air-conduction stimulation there again was a reliable response, but only for intensity levels greater than 60 to 65 dB nHL and with delayed absolute latencies. Interwave latency values were within the age-corrected normal region. Bone-conduction stimulation at the mastoid, however, produced a reliable ABR for intensity levels within normal limits (less than 30 dB nHL). A clear wave I was present for the ipsilateral inverting electrode channel on each side, implying that the bone-conduction ABR findings were ear specific (Hall, 1992a). Hearing aid management was recommended, pending follow-up ABR assessment in the clinic 1 month later. The patient returned 3 months later (at 1 year of age). Behavioral assessment was first attempted, but results were inconclusive. A third ABR assessment was then carried out (with sedation). At high stimulus intensity levels there was a clear ABR. Interwave latencies were normal for the patient's age. No air-conduction ABR was observed below 70 dB nHL for either ear for click or 500-Hz tone-burst stimuli, whereas there was a normal-appearing response for bone-conduction click stimulation. The patient was then referred for hearing aid fitting and appropriate educational management.

Comment. Consistent with the limited literature on auditory function in Carpenter syndrome (Robinson et al, 1985), our patient had recurrent middle ear disease and persistent conductive hearing impairment bilaterally. The severe degree of conductive hearing loss, even immediately after myringotomy with placement of ventilation tubes, strongly suggested the possibility of a structural ossicular chain deformity, in addition to otitis media. Resolution of normal middle ear function and return to normal hearing cannot be presumed following either medical or surgical treatment of middle ear disease. Only a valid auditory assessment can document hearing status after treatment. In this case, behavioral audiometry was not of value in defining the patient's auditory status during the first year of life. ABR, however, repeatedly confirmed the presence of a severe conductive hearing loss and contributed to confident and reasonably prompt audiologic management.

Case 2: Ichthyosiform Dermatosis

Background. Ichthyosiform dermatosis is not a specific syndrome but, rather, a classification of skin disorders that is characterized by ichthyosis (dry and flaky skin resembling fish scales) and alopecia (absence of hair). It may be a feature of various syndromes, such as Refsum, Sjorgren-Larsson, Rud, and Netherton syndromes. In 1978, Senter and colleagues reported a 13-year-old child with ichthyosiform dermatosis, plus congenital sensorineural hearing loss and ocular abnormalities, and also identified 12 other children reported in the literature with a similar pattern of findings (Senter et al, 1978). Another case was reported by Cram and colleagues a year later (Cram et al, 1979) and more recently by others (Skinner et al, 1981; Morris et al, 1991). This apparently distinct disorder has since been referred to as Senter syndrome. Typical physical findings may include very dry, red, scaly skin, no scalp hair, abnormalities of the teeth and nails that vary in severity, progressive corneal abnormalities (vascularization) leading to blindness, neuromuscular defects, deficient growth, and congenital sensorineural hearing loss. Sensorineural hearing loss is apparently a consistent finding in Senter syndrome, whereas it is only an occasional feature of two of the other syndromes — Refsum and Rud — that include ichthyosiform dermatosis.

Clinical Findings. The patient was a boy who first was evaluated at the audiology clinic at the age of 3 months. He was the 2800-gram product of a 37-week gestation. At birth, the patient was blue with poor respiratory effort. Apgar scores at birth were 2 at 1 minute and 5 at 5 minutes. Physical examination showed loose, peeling skin over the entire body, facial edema with tight skin, reddened and tight eyelids, a flattened nose, and a constricted mouth. Ears were low set with abnormally formed ear lobes. Ear canals were present. The patient was admitted to the neonatal intensive care unit and examined by the genetics and ophthalmology services.

The patient was at risk for hearing loss at birth (asphyxia). He underwent hearing screening in the NICU prior to hospital discharge and did not pass. He returned for follow-up audiologic assessment 10 weeks after birth. Otoscopic inspection showed excessive dry skin and hard

debris in each ear canal. An ABR assessment yielded a response bilaterally for air-conduction stimuli at intensity levels down to 40 to 50 dB nHL. Absolute wave latencies were delayed, suggesting a conductive hearing loss. A bone-conduction stimulus ABR was observed for intensity levels that were within normal limits (less than 30 dB nHL). The patient was reassessed 1 month later after his ear canals were cleaned (the day before) by his otolaryngologist. A reliable ABR was observed bilaterally at 35 dB nHL. Behavioral observation audiometry in the sound field produced a minimum response level within normal expectations. Startle responses were observed for a 2000-Hz warbled tone and speech stimuli. Regular otologic management of ear canal debris was recommended, along with periodic behavioral audiologic assessment to monitor hearing status.

Comment. Although congenital sensorineural hearing loss is considered a feature of Senter syndrome, published reports also describe the development, or at least detection, of varying degrees of high-frequency, sensorineural hearing loss and occasional conductive hearing loss during childhood (Senter et al, 1978; Cram et al, 1979). Whether the sensorineural hearing loss is delayed in onset or present from birth, but not adequately assessed until age 1 or 2 years or older, is unclear from the literature. We plan to monitor our patient's hearing status with behavioral audiometry, immittance measures, otoacoustic emissions, and, if indicated, ABR. Prior to these measures, it will be necessary to ensure that the ear canal is free of debris. Also, ongoing, careful attention to the condition of the external ear canal will be required to prevent recurring conductive hearing loss due to excessive debris.

Case 3: Townes Syndrome

Background. Townes syndrome (also known as Townes-Brocks syndrome) was described first in 1972 by Townes and Brocks and then 10 years later by Walpole and Hockey (1982). It is autosomal dominant with variable expression. Townes syndrome is characterized by imperforate anus; hypoplastic, triphalageal, or supernumery thumbs; other bony abnormalities of the hands and feet; and sensorineural hearing loss. In the original report (Townes and Brocks, 1972), these findings were described for a father and five of his children. Although mild or moderate "sensorineural deafness" was noted for the family members, no audiometric data or other hearing findings were specified. The second paper (Walpole and Hockey, 1982) reported findings for a 31-year-old woman and her stillborn offspring. When the woman was 6 years old, a 40-dB high-frequency (1000 to 4000 Hz) sensorineural hearing loss was identified. It is relevant to note at this point that familial hand abnormalities and sensorineural hearing loss may also be

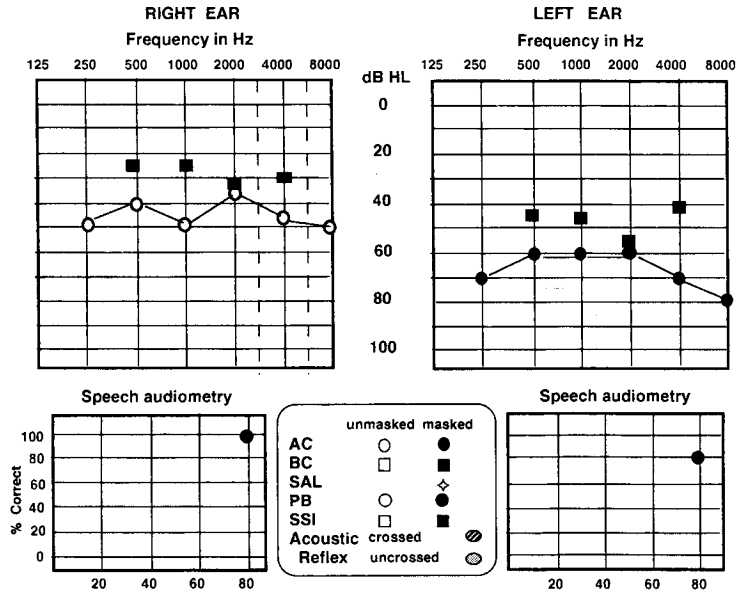

Figure 2 Audiogram for a 5-year-old girl with Townes syndrome showing a mixed hearing loss bilaterally, greater for the left ear. ABR findings are shown in Figure 3.

features of other syndromes (Stewart and Bergstrom, 1971).

Clinical Findings. Our patient was 5 years old when she underwent audiologic evaluation. At birth, she was 2400 grams at 37 weeks' gestational age. Respiratory effort was poor, and Apgar scores were 3 at 1 minute and 6 at 5 minutes. Physical examination showed imperforate anus (not patent), a supernumerary thumb bilaterally, satyr-type ears (small and cupped appearance), and absence of cartilage in the left ear. A renal disorder (single kidney) was later identified. The patient underwent surgical repair of the imperforate anus. She was followed by the genetics clinic. At the time of the audiologic evaluation, the patient was well developed and well nourished. Her facial features were unremarkable, with the exception of her external ears.

Audiometric assessment showed a mixed hearing loss bilaterally, greater for the left ear (Fig. 2). Middle ear function was abnormal for the right ear by aural immittance measurement (high negative pressure and excessive compliance for the right ear). Immittance measures could not be obtained for the left ear. Word recognition scores were good. A reliable ABR was recorded bilaterally for air-conduction stimulus intensity levels of 95 dB nHL down to 60 dB nHL for the right ear and 70 dB nHL for the left ear (Fig. 3). A bone-conduction stimulus ABR was observed only at the maximum intensity level (50 dB nHL) and only for the right ear (right mastoid placement of the bone oscillator). Two months later, the patient underwent bilateral myringotomies and placement of ventilation tubes. Thick middle ear effusion was aspirated from each middle ear during surgery. Audiologic management included bilateral amplification. Follow-up revealed that the patient was attending kindergarten and adjusting to hearing aid use.

Comment. Although nonspecific sensorineural hearing loss has been associated with Townes syndrome, this is, to our knowledge, the first published case for which detailed audiologic findings are reported. The case illustrates that the sensorineural hearing loss in Townes syndrome is sufficient to interfere with communication and to require hearing aid use. An asymmetry in sensorineural hearing deficit may also occur. It is not clear whether this patient's conductive hearing loss component was related to the syndrome or occurred independently. The patient's speech-language development was not delayed. While it is possible that the hearing loss has progressed during early childhood, the sensorineural hearing loss for the right ear (bone-conduction, pure-tone threshold of less than 30 dB HL) is not inconsistent with essentially normal speech-language development.

CONCLUSIONS

Hundreds of syndromes may be associated with hearing impairment. Unfortunately, many of the papers that cite hearing impairment as a component of a particular syndrome were published before audiologic techniques for differentiation among types of hearing loss or for valid assessment of infants and young children were available. And even more recent literature often does not precisely describe auditory status in syndromes. Our understanding of the auditory dysfunction associated with syndromes will be enhanced by assessment with current behavioral and electrophysiologic assessment techniques. In addition, audiologic assessment of family members would contribute to an appreciation of the natural history and genetic expression of auditory dysfunction in syndromes.

It is clear from our review of the literature that the hearing impairment associated with

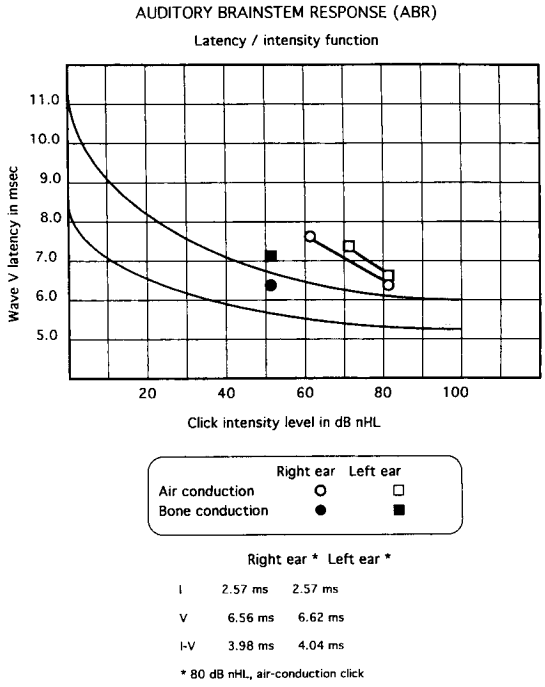

Figure 3 ABR findings for a 5-year-old girl with Townes syndrome confirming a moderate hearing sensitivity loss bilaterally, greater for the left ear. The patient's audiogram is shown in Figure 2.

syndromes can be highly varied, ranging from surgically and/or medically treatable conductive deficits to sensory hearing loss requiring amplification to central auditory dysfunction with or without a peripheral component. Middle ear disease, and conductive hearing impairment, appears to be especially prevalent. Therefore, a comprehensive strategy for audiologic assessment employing the cross-check principle (Jerger and Hayes, 1976) and state-of-the-art diagnostic and hearing aid techniques (Hall, 1987, 1992a, b, 1993; Mueller et al, 1992) is required to adequately describe hearing status in syndromes and to manage the hearing impairment promptly and appropriately.

Physical findings in the majority of syndromes include a well-known risk factor for hearing impairment, namely "craniofacial anomalies, including abnormalities of the pinna and ear canal..." (Joint Committee on Infant Hearing, 1990, p. 15). These anomalies are usually detected at birth, and hearing assessment, or screening, can be initiated without delay. However, not all hearing impairment associated with syndromes is congenital and present, or suspected, at birth. Some syndromes are characterized by late, even adult, onset of sensorineural hearing loss (Cruz et al, 1992). For children with these syndromes, prudent management strategy includes periodic monitoring of auditory status to assess the possibility of progressive or delayed-onset hearing impairment, with changes in the intervention plans as indicated.

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