ABSTRACT: The majority of reported cases of auditory neuropathy are due to genetic factors or are of idiopathic origin. Deltenre, Mansbach, Bozet, Clercx, and Hecox (1997) were the first to describe auditory neuropathy as related to central nervous system insult in infants. The auditory physiological function of patients with auditory neuropathy has been reported as stable over time (Konradsson, 1996) or to have shown improvement (Stein, Tremblay, Pasternak, Banerjee, Lindemann, & Kraus, 1996). Earlier reports of possible auditory neuropathy were made by Worthington and Peters (1980) and Kraus, Ozdamar, Stein, and Reed (1984). However, diagnostic equipment and techniques necessary for its determination were unavailable at the time. The classic description of auditory neuropathy is that patients display normal cochlear outer hair cell function and abnormal neural function of the most distal portion of the eighth nerve, possibly including cochlear inner hair cells, eighth nerve dendritic connections, and spiral ganglion. Outer hair cell integrity is determined by the presence of otoacoustic emissions, whereas neural dysfunction is determined by the absence of an auditory brainstem response (ABR). The absence of any space-occupying lesion is ruled out by normal results following radiological evaluation.

There is no gender preference, and patients of all ages from infants to young children to adults have been reported in the literature as having been diagnosed with auditory neuropathy (Deltenre, Mansbach, Bozet, Clercx, & Hecox, 1997; Starr, Picton, Sininger, Hood, & Berlin, 1996; Stein, Tremblay, Pasternak, Banerjee, Lindemann, & Kraus, 1996). Older patients on which behavioral audiometric data can be reliably obtained typically present with bilateral pure-tone hearing loss of varying degree and configuration with poorer speech understanding than can be accounted for by the pure-tone audiogram. Possible underlying etiologies in auditory neuropathy may include genetic diseases such as...
Charcot-Marie-Tooth, Fredrich’s ataxia and mitochondrial disease (Berlin, Hood, Hurley, & Wen, 1994; Corley & Crabbe, 1999; Starr et al., 1996), hyperbilirubinemia (Rance et al., 1999; Stein et al., 1996), and complicated perinatal periods with multiple factors that might result in central nervous system insult (Deltenre et al., 1997). The greatest number of auditory neuropathy cases are reportedly due to genetic factors or are of idiopathic origin (Starr, 1998).

The purpose of this article is to report on an infant who originally presented with a more central pathology within the cortex and rostral brainstem, which over time progressed to what is now described as auditory neuropathy. To the author’s knowledge, there have been no reports of such a finding in the research literature.

**CASE REPORT**

**History**

The infant was born premature at 33 weeks post-conceptional age as a fraternal twin. The infant was the smaller twin, weighing 2 pounds 11 ounces and taken by cesarean section due to intrauterine arrest of growth. The infant presented with microcephaly and global hypotonia with absent Moro reflex. Mitochondrial disease was ruled out. A magnetic resonance imaging (MRI) showed abnormal cortical gyri with underdeveloped corpus callosum and brainstem. Subsequent to discharge from the neonatal intensive care unit, the infant developed an upper respiratory infection that eventually led to a staphylococcal meningitis. Following recovery, the infant was transferred to our tertiary care hospital, where a speech-language pathologist noted discoordination of pharyngeal muscles during a modified barium swallow.

**Audiological Assessment**

Physiological data were gathered on the infant once normal middle ear status was observed by physician’s otoscopic and audiologist’s tympanometric evaluations. All ABR recordings were obtained using a Biologic Traveler auditory-evoked potential system (Mundelein, IL). Recordings were made between the forehead and ipsilateral mastoid, with the opposite mastoid used as ground. Bandpass filtering was set between 100 and 3000 Hz, with manual and automatic artifact rejection constantly applied. Alternating polarity click stimuli were presented at intensities up to a maximum of 90 dB nHL via electromagnetically shielded earphones at a stimulus rate of 19.1 clicks per second. Click stimuli with alternating polarity were chosen to eliminate the polarity sensitive cochlear microphonic and focus solely on the neural components of the brainstem response. Two averaged response recordings of 2,000 samples were obtained at all but one intensity level. All physiological recordings were completed without the use of sedation.

Distortion product otoacoustic emissions (DPOAEs) were recorded via a Grason-Stadler GSI 60 unit (Milford, NH). Tone pair was sequential, with an F2/F1 ratio of 1.2. Intensity of the tone pairs was 65 and 55 dB SPL for L1 and L2, respectively. Two separate runs per ear were collected for determining repeatability. Validity and reliability of normal outer hair cell function was determined by analyzing each distortion product frequency separately. Each distortion product amplitude had to be greater than or equal to –10 dB, and the distortion product amplitude minus the noise floor difference had to be greater than or equal to 5 dB.

**Audiometric Test Results**

The infant was subsequently referred to our facility for further diagnostic audiometry due to a failed newborn hearing screen using ABR audiometry at an acute care hospital. The following test results were gathered at our tertiary care hospital over a 5-month period from admission until final hospital discharge. The time period was concurrent with the infant’s corrected chronological age of 6 months through 11 months.

At age 6 months, diagnostic (ABR) audiometry was attempted without sedation and only partially successful due to the patient’s state of arousal. Three days later, the initial diagnostic ABR was once again attempted and completed, with results displayed in Figure 1. For the left ear, there appeared to be a response at 75 dB nHL, but with only waves I and III present, indicating brainstem abnormality. For the right ear, more definitive results are shown, with waves I, II, and III present at appropriate latencies at all intensities but, once again, with absence of waves beyond wave III indicative of brainstem abnormality. DPOAEs were administered and interpreted according to guidelines stated earlier. DPOAE test results at F2 indicated repeatable islands of normal outer hair cell function at the 1500, 3031, and 3812 Hz region of the cochlea for the right ear and the 3812 and 4812 Hz region for the left ear (see Figure 2). Noise interference from a restless infant negated further possible repeatable responses at frequencies of 1906 Hz and below.

Diagnostic ABR was used to monitor the integrity of the auditory brainstem pathway at approximately 2 months following the initial ABR. The ABR results for both ears showed an elevated threshold response at 75 dB nHL with continued presence of brainstem abnormality due to the absence of later waves. However, in the left ear, there appeared to be a significant deterioration of wave III, with only waves I and II present. The right ear also showed deterioration of waves I, II, and III being recognizable only at higher intensity levels (see Figure 3). During the next 2 months, the infant developed several episodes of bilateral otitis media, which were treated with an antibiotic regimen. No audiometric testing other than tympanometry was administered during this time.

Approximately 3 months later, at age 11 months, ABR and DPOAEs were once again administered. At this time, the infant’s overall condition had stabilized and the infant was about to be discharged from the hospital to the parents’ home. The ABR had showed further deterioration to the degree that all waves were absent at all intensity levels in both ears, as shown in Figure 4. In other words, a
complete absence of a neural response from either ear existed. Repeated DPOAEs continued to show islands of normal outer hair cell function bilaterally, within and between the two DPOAE test sessions (see Figures 2 and 5). Between the two test sessions, repeatable DPOAEs were seen at 1500 and 3812 Hz in the right ear and at 3812 Hz in the left ear. Additional normal outer hair cell results were found at 1906 Hz in the right ear and at 1187, 1500, and 6031 Hz in the left ear in the second test session (Figure 5) that were not present in the first test session (Figure 2). The former result indicating consistency in normal outer hair cell function from initial to final DPOAE testing and the latter result evidence of a possible return of some additional normal function. The evidence of additional normal outer hair cell function demonstrated in the final test session is not questioned; however, there are alternate explanations for it not being present in the initial DPOAE. The most obvious possibility is the noise interference masking the response at the lower frequencies for the left ear (Figure 2). Second, although at the time of the initial DPOAE, otoscopic and tympanometric results were normal, the presence of a subacute or subtle middle ear pathology could have prevented the recording of a repeatable response (Lonsbury-Martin, Whitehead, & Martin, 1991). Further support for this hypothesis is found in the fact that a bilateral otitis media did indeed develop following the initial DPOAE test session.

DISCUSSION

Auditory neuropathy encompasses a broad diagnostic label. Rather than a single neuropathy affecting just the auditory pathway, many patients have additional multiple neuropathies outside the auditory pathway. The majority of cases reported are of genetic or idiopathic origin (Starr, 1998). It can occur in infants or later in life as children or adults (Deltenre et al., 1997; Rance et al., 1999; Starr et al., 1996). In older patients, children and adults show pure-tone sensitivity of normal to severe to profound loss that could be unilateral or bilateral, symmetrical or asymmetrical (Doyle, Sininger, & Starr, 1998; Hood & Sininger, 2000; Konradsson, 1996). Although specific site(s) and mechanisms for its expression have yet to be determined, all patients with auditory neuropathy have in common the finding of normal outer cell function and absent or grossly abnormal auditory brainstem function.

Another variable characteristic of auditory neuropathy is the stability or lack thereof of auditory physiological function. Rance and colleagues (1999) and Konradsson (1996) tested infants and children over a period of several months to several years and found their patients to have stable OAE and ABR results. On the other hand, Stein et al. (1996) and Stein, McGee, Tremblay, Kraus, and Cheatham (1997) showed that over a period of months, several of their patients with auditory neuropathy had improved auditory physiological function in the form of improved waveform morphology and the appearance of later waves III and V of the ABR.

In the present study, I report a case of progressive deterioration of physiological function that has not as yet been reported in the literature. Over the course of 5 months, a grossly abnormal ABR with the presence of only waves I, II, and III deteriorated to total absence of all neural components. Like Deltenre et al. (1997), auditory neuropathy was secondary to major neonatal pathologies. In addition, a peculiar coincidence of my infant patient and two of the three infant patients of the Deltenre study was that each one was the most medically fragile infant in twin births.
The management of patients with auditory neuropathy poses a formidable challenge. Most reports in the literature of children and adults with auditory neuropathy indicate that their auditory behavioral function is similar to patients with auditory processing disorders. Characteristics such as poorer speech recognition in quiet than can be accounted for by the degree of pure-tone loss and generally poorer speech recognition when the speech signal is degraded will occur. Personal amplification by hearing aids, FM systems, or cochlear implants has shown limited benefit (Miyamoto, Kirk, Renshaw, & Hussain, 1999; Rance et al., 1999). The limited benefit is probably due to our lack of understanding the specific site of lesion, the underlying etiologies, and the variability in functional expressivity of this disorder.

The implication of this study is that infants who show an abnormal or absent ABR should automatically receive an OAE evaluation for proper identification of auditory disorder. If auditory neuropathy is found, then long-term monitoring of auditory physiological and behavioral function should be part of the case management for that patient.
Figure 3. Top: Interim auditory brainstem response (ABR) results for the right ear. Bottom: Interim ABR results for the left ear.

Figure 4. Top: Final auditory brainstem response (ABR) results for the right ear. Bottom: Final ABR results for the left ear.

REFERENCES


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