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Performance after Cochlear Implantation in Children with Auditory Neuropathy

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Introduction

Auditory neuropathy is a group of disorders typically characterized by hearing loss in the presence of otoacoustic emissions and, in older subjects, audiometric thresholds which do not correlate with speech understanding scores. Also known as 'auditory neuropathy spectrum disorder' and 'auditory dys-synchrony', this cause of hearing loss is more difficult to detect on newborn hearing screening (NHS) as tests for otoacoustic emissions are typically normal. However, auditory brainstem response (ABR) testing typically demonstrates very abnormal or absent waveforms. A large cochlear microphonic is also characteristically seen on ABR testing in auditory neuropathy.

In this condition, the possible sites of auditory dysfunction are the inner hair cells, inner hair cell-cochlear nerve junction, cochlear nerve, and central auditory nervous system. Auditory neuropathy may occur as an isolated condition or as part of a syndrome, such as Charcot-Marie-Tooth syndrome or Friedreich's ataxia. Risk factors for auditory neuropathy in the newborn include hypoxia, hyperbilirubinemia, and genetic disorders (such as the 'otoferlin' gene). As a result, neonates with these specific risk factors for auditory neuropathy or other non-specific risk factors such as admission to a neonatal intensive care unit (NICU) are typically screened for hearing loss with ABR rather than otoacoustic emissions.

Animal models of auditory neuropathy have been developed. Auditory neuropathy-like symptoms can be induced in chinchillas receiving carboplatin through the destruction of inner hair cells (Harrison, 1998). Chinchillas exposed to chronic mild hypoxia also develop auditory neuropathy (Sawada et al., 2001). Auditory neuropathy occurs in certain genetic strains of mice, such as the Bronx waltzer mouse (Bock et al., 1982).

As individuals with auditory neuropathy typically have degradation of speech recognition disproportionate to the degree of hearing loss, conventional amplification

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is often of marginal benefit. There has been reluctance to consider cochlear implantation in children with auditory neuropathy due to the possibility of limited benefit (Gibson & Graham, 2008).

The purpose of this exploratory study was to evaluate audiologic performance after cochlear implantation in children with auditory neuropathy.

Methods

In this retrospective study, children with clinical evidence of auditory neuropathy undergoing cochlear implantation at the University of Ottawa Auditory Implant Program were evaluated. Outcomes after implantation in children with auditory neuropathy were compared to children with other causes of sensorineural hearing loss (SNHL). Clinical records from the cochlear implant program at the Children's Hospital of Eastern Ontario were examined to identify all children with pre-lingual onset of bilateral severe-profound SNHL who had undergone implantation under 12 years of age.

Each child with auditory neuropathy undergoing implantation was matched to two children with other SNHL aetiologies. Primary matching variables were age at implantation and developmental status. Where possible, subjects were also matched on two secondary variables, NICU admission and aetiology of hearing loss. All individuals with auditory neuropathy had evidence of a structurally normal cochlear nerve on magnetic resonance imaging. All children did not receive significant benefit from a prior trial of conventional amplification. Children with complex medical developmental issues were not included in this outcomes analysis.

The Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) is a structured questionnaire that measures a child's spontaneous responses to everyday sounds. IT-MAIS results of the two subject groups pre-implantation and approximately one year after implantation were compared. Additionally, age-appropriate audiologic outcomes of children with auditory neuropathy were compared to the matched children with other SNHL aetiologies.

Results

Sixteen children with auditory neuropathy underwent cochlear implantation at the Children's Hospital of Eastern Ontario. Eighty-nine children with other SNHL aetiologies undergoing implantation fulfilled the inclusion criteria for the comparison group. Patient characteristics of the two groups of children are presented in Table 1. A significantly greater proportion of children with auditory neuropathy were identified through NHS compared to children with other SNHL aetiologies (Fisher's Exact, $p < 0.005$). Children with auditory neuropathy were more likely to have a history of NICU admission compared to those with other SNHL aetiologies (Fisher's Exact, $p < 0.05$). The two groups were similar in gender, age at confirmation of hearing loss, age at diagnosis of profound hearing loss, and age at cochlear implantation (Mann-Whitney U, $p > 05$).

Ten children were eligible for the IT-MAIS and age-appropriate audiologic outcomes comparison. Six children who had complex developmental issues were

TABLE 1

DESCRIPTIVE STATISTICS FOR PATIENT CHARACTERISTICS

Variable	Auditory neuropathy	Other SNHL
Male	10	52
Female	6	37
Referral route:		
Identified through NHS	13 (81.3%)	37 (41.6%)
Referred by physician	3 (18.7%)	52 (58.4%)
Age of hearing loss diagnosis (months)	7.3	9.5
Age of profound hearing loss (months)	11.4	12.5
Age of cochlear implantation (months)	31.7	28.1
Aetiology or risk factors:		
• NICU admission	10 (62.5%)	23 (25.8%)
• Genetic	2 (12.5%)	11 (12.4%)
• Syndromic	2 (12.5%)	7 (7.9%)
• Unknown	2 (12.5%)	48 (53.9%)
Total	16	89

excluded from the analysis. Each child with auditory neuropathy was matched with two children with other SNHL aetiologies. For one child with auditory neuropathy, only a single appropriate match could be found.

IT-MAIS results prior to implantation were available for 21 children (8 with auditory neuropathy, 13 with other SNHL aetiologies). Children with auditory neuropathy had lower pre-implant IT-MAIS scores compared to those with other SNHL aetiologies (Mann-Whitney U, $p < 0.037$). IT-MAIS results one year after implantation were available for 15 children (5 with auditory neuropathy, 10 with other SNHL aetiologies). There was no significant difference in the IT-MAIS scores one year after implantation between the two groups (Mann-Whitney U, $p = 0.679$).

Age-appropriate audiologic outcomes were compared within individual matched groups of children. Overall, there was no marked difference in outcomes in the matched children. Selected matched groups with age-appropriate audiologic outcomes comparisons are presented in Figures 1–3.

In this matched group, the child with auditory neuropathy and the two children with other SNHL aetiologies underwent implantation between 11.4 and 11.7 months of age. All had very low pre-implant IT-MAIS scores (range: 2.5–15). Twelve months post-implantation, all three children had similar IT-MAIS results (range: 75–85). The Glendonald Auditory Screening Procedure (GASP) word identification score is presented. The GASP test was administered at times using live voice and in a therapy room setting. All other word and sentence identification tests were administered at 70 dB SPL in a calibrated sound suite. All three children had similar results on the GASP test at 18 months post-implantation (range: 66.7–75).

In this matched group, the child with auditory neuropathy and the two children with other SNHL aetiologies underwent implantation between 12.1 and 14.7 months of age. The Multisyllabic Lexical Neighbourhood Test (MLNT) is a paediatric

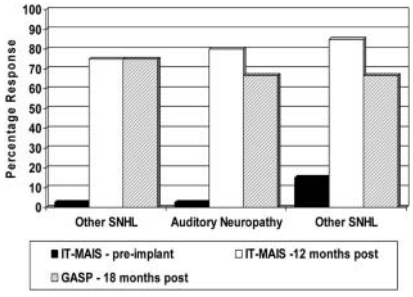

FIGURE 1 Matched group undergoing cochlear implantation at approximately 12 months of age.

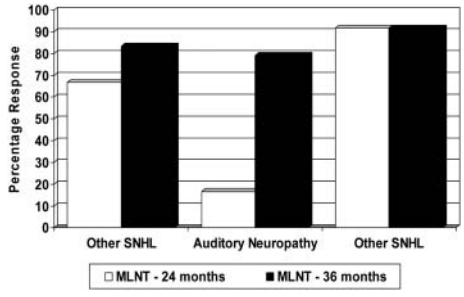

FIGURE 2 Matched group undergoing cochlear implantation between 12 and 15 months of age.

open-set test of word recognition. The child with auditory neuropathy had a markedly lower score (16.67) on the MLNT test 24 months post-implantation compared to the 2 matched children (66.7, 91.7). However at 36 months post-implantation, the child with auditory neuropathy had a similar result (79.17) on the MLNT test compared to the 2 matched children (83.3, 91.7).

In this matched group, the child with auditory neuropathy and the 2 children with other SNHL aetiologies underwent implantation between 28.1 and 33.5 months of age. Comparison of age-appropriate audiologic outcomes 5 years after implantation yielded variable results depending on the test measure utilized. The child with auditory neuropathy had a markedly lower score (54.17) on the MLNT test compared to the 2 matched children (83.3, 83.3).

The Phonetically Balanced Kindergarten Test (PBK) is a paediatric open-set test of monosyllabic word recognition. The child with auditory neuropathy had a slightly lower score (48) on the PBK test compared to the 2 matched children (64, 64).

The Hearing in Noise Test for Children (HINT-C) is an open-set test of sentence identification. The child with auditory neuropathy had a similar score (76) on the HINT-C test compared to the 2 matched children (78.4, 78.9).

Discussion

In this exploratory study, performance in children with auditory neuropathy undergoing cochlear implantation was found to be similar to children with SNHL due to other aetiologies. IT-MAIS results one year after implantation were not statistically different between the two groups. Age-appropriate auditory outcomes were generally similar within the individual matched groups. All children with auditory neuropathy had evidence of a structurally normal cochlear nerve on magnetic resonance imaging. Individuals with hypoplastic auditory nerves on MRI generally have poor outcomes after implantation (Bradley et al., 2008).

There are two commonly proposed causes of auditory neuropathy. First, auditory neuron pathology (e.g., de-myelination) which results in altered axonal conduction times and dys-synchrony of evoked neural activity, and which could account for abnormal ABR potentials (Starr et al., 1996). Secondly, there is a large reduction in the number of neurons (and hence 'channel capacity') of the cochlear nerve (Harrison,

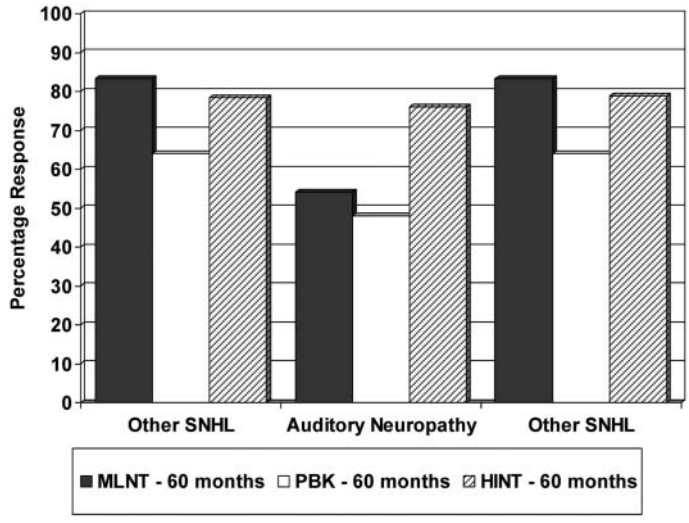

FIGURE 3 Matched group undergoing cochlear implantation between 28 and 34 months of age.

1998). Perhaps it is not surprising that many individuals with auditory neuropathy do well with a cochlear implant. The precise timing of nerve activation from implant electrode stimulation may well improve neural synchrony. In the case of poor channel capacity, the imposition of a small number of very effective cochlear implant stimulation channels may well be an improvement on, or augment, the few existing neural connections.

There are several limitations to this retrospective study. The finding of no significant difference between the outcomes of the auditory neuropathy group and the children with other causes of SNHL may be due to the small number of subjects. Case-control studies are potentially subject to bias. Subjects were matched on the basis of two primary and, if possible two secondary variables. Other variables, not controlled for in this study may also influence auditory outcomes after implantation. The results of this study should not be considered confirmatory. Rather, these findings justify further evaluation of the auditory outcomes after cochlear implantation in children with auditory neuropathy.

Conclusions

Cochlear implantation should be considered in children with auditory neuropathy who derive minimal benefit from hearing aids and have evidence of a structurally normal cochlear nerve on MRI. The findings of this exploratory analysis should be confirmed by a multi-centre study or meta-analysis.

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