Neural Response Telemetry Thresholds in Patients with Cochlear Nerve Canal Stenosis

Shuguang Han, MD¹, Line Wang, MD¹, Daoxing Zhang, MD¹, and Kevin Peng, MD²

Abstract

Objective. To explore neural response telemetry (NRT) thresholds in patients with stenotic versus normal cochlear nerve canals.

Study Design. Case series with chart review.

Setting. Tertiary referral center.

Subjects and Methods. Thirty pediatric patients with profound sensorineural hearing loss in at least 1 ear and no benefit from amplification underwent computed tomography imaging of the temporal bones. They were divided into 3 groups according to the diameter of the cochlear nerve canal: group A, <1.5 mm; group B, 1.5 to 1.7 mm; group C, 1.8 to 2.1 mm. All patients underwent cochlear implantation with full insertion of all electrodes. NRT was performed both intraoperatively and 6 months postoperatively in all patients; thresholds of electrodes 1, 11, and 22 were compared.

Results. Per analysis of variance, intraoperative and 6-month postoperative NRT thresholds were both significantly different among groups A, B, and C at electrodes 1 and 22 but not at electrode 11. On intergroup analysis, group A showed statistically higher thresholds than those of groups B and C; however, no difference was found between groups B and C.

Conclusion. Cochlear nerve canal stenosis, defined as a canal diameter <1.5 mm, is associated with significantly increased NRT thresholds, which may play a role in postimplant performance.

Keywords
cochlear nerve deficiency, cochlear nerve canal stenosis, cochlear implantation, neural response telemetry

Cochlear nerve deficiency (CND) is a broad term describing patients with radiologic absence of the cochlear nerve as well as patients demonstrating hypoplasia of the cochlear nerve as visualized on magnetic resonance imaging (MRI).¹ It is strongly associated with hypoplasia of the internal auditory canal (IAC) as well as stenosis of the cochlear nerve canal (CNC), both of which are well visualized on computed tomography imaging.²,³ Contrary to previous theories, it is now understood that CNC stenosis and CND can occur in the setting of a fully developed cochlea and an intact organ of Corti.⁴,⁵ Still, CNC stenosis is almost always accompanied by a diagnosis of sensorineural hearing loss (SNHL), and up to 10% of pediatric hearing loss may be associated with CNC stenosis.⁶,⁷ Although a consensus is lacking in the literature, it is generally accepted that a normal CNC must exceed 1.5 mm in diameter; below this value, a CNC is considered stenotic.⁸,⁹

Cochlear implantation has emerged as the most effective method for restoring auditory function in children with bilateral prelingual severe or profound SNHL. However, patients with CNC stenosis pose unique challenges: while cochlear implantation has been performed on these patients, varying postoperative hearing results are reported in the literature.¹⁰,¹¹ In one study, serviceable hearing was achieved in only 19% of CND patients after implantation, significantly worse than patients with isolated inner ear malformations.¹² Preimplantation counseling is accordingly challenging.

Little has been published to correlate the degree of CNC stenosis with cochlear implant function. To assess this, we chose to utilize neural response telemetry (NRT), which has proven to be a powerful tool in assessing electrically evoked cochlear nerve action potentials in the intraoperative and postoperative settings.¹³ We hypothesized that NRT thresholds intraoperatively and postoperatively would vary with the severity of CND, possibly offering implications for postimplant hearing performance.

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Materials and Methods

Subjects

The institutional review board of the Beijing Friendship Hospital, Capital Medical University, approved this study. Inclusion criteria were as follows: a diagnosis of profound SNHL from May 2012 to July 2013, presence of a cochlear nerve on MRI (Figure 1), hearing aid use for at least 6 months without hearing benefit, and type A tympanometry. High-resolution temporal bone computed tomography imaging was performed on all patients.

The 30 patients identified were divided into 3 groups, each containing 10 patients, according to CNC diameter as seen on computed tomography imaging: group A, CNC diameter <1.5 mm; group B, between 1.5 and 1.7 mm; group C, between 1.8 and 2.1 mm (Figure 2). By convention discussed above,9 group A comprised patients with CNC stenosis, while groups B and C comprised patients with normal CNC caliber.

Twenty-three patients were implanted with CI24RE Freedom and the other 7 with CI24RCA electrodes (Cochlear Corporation, Australia). Intraoperative plain films were used to confirm complete insertion, which was attained in all cases.

Neural Response Telemetry

All patients underwent intraoperative NRT evaluation following placement of the electrode into the cochlea, and the current level (CL) thresholds of electrodes 1, 11, and 22 were recorded. NRT was repeated in all patients 6 months after surgery.

Statistical Analysis

Data were analyzed with SPSS 19.0 statistical software (IBM, Armonk, New York), first using 1-way analysis of variance (ANOVA), followed by Tukey’s test for post hoc analysis, to compare intraoperative and postoperative NRT thresholds in the 3 groups of patients.

Results

Demographic data, in addition to intraoperative and 6-month postoperative NRT thresholds for all groups, are reported in Table 1. No statistically significant difference was noted regarding the average age of patients in the 3 groups (1-way ANOVA, $F = 1.06, P = .36$). Overall, thresholds were greater in group A (CNC stenosis) than in groups B and C. Within each group, there was no significant difference between intraoperative and 6-month postoperative NRT thresholds. Electrode 11 was generally associated with higher NRT thresholds than electrodes 1 and 22 were.

Based on 1-way ANOVA, a significant difference was observed among the 3 groups when the intraoperative thresholds of electrodes 1 and 22 were compared ($P < .001$, statistically significant according to a Bonferroni-adjusted alpha level of 0.017). Similarly, a significant difference was observed among the 3 groups when the 6-month postoperative thresholds of electrodes 1 and 22 were compared ($P < .001$). However, there was no significant difference among the 3 groups when the NRT of electrode 11 was compared in both intra- and postoperative settings ($P = .428$ and $P = .244$, respectively; Table 2).

Post hoc intergroup analysis was performed using Tukey’s test to elucidate the significant findings seen on...
ANOVA testing. This revealed that thresholds were statistically significantly greater in group A than either of the 2 remaining groups when intra- and postoperative NRT thresholds of electrodes 1 and 22 were considered. However, comparisons between groups B and C revealed no statistically significant difference (Table 3).

**Discussion**

Glastonbury et al defined CND as an absent (aplastic) or thin (hypoplastic) cochlear division of the eighth cranial nerve, regardless of whether the etiology of the deficiency was congenital or acquired following degeneration. Various reports have emphasized the correlation between CNC stenosis and the presence of CND, with smaller CNC diameters corresponding to higher risks of CND. A consensus is lacking, most agree that the diameter of a normal CNC exceeds 1.5 mm, while diameters <1.5 mm are usually considered stenotic.

CND is almost always accompanied by profound SNHL. Both CND and CNC stenosis are observed in a significant proportion of patients presenting with the phenotype of auditory neuropathy spectrum disorder, with estimates ranging from 18% to 27%. Outcomes following cochlear implantation in patients with CND are generally poorer than in patients with isolated inner ear malformations, but individual results vary greatly. As a result, implant candidacy in this population remains nebulous, and preoperative counseling is challenging.

NRT, which has evolved significantly since its introduction in the late 1990s, is widely used intraoperatively to confirm appropriate placement of cochlear implants. It additionally serves as a springboard for implant programming by offering baseline parameters for processor settings. NRT remains reproducible even in the setting of inner ear malformations and CNC stenosis.

We hypothesized that the degree of CNC stenosis would correlate with intraoperative and 6-month postoperative NRT thresholds, and we chose to analyze the response of electrodes 1, 11, and 22 to investigate this. We stratified patients by the CNC diameter. Group A corresponded to stenosis, with CNC diameter <1.5 mm; group B contained subjects with normal CNC diameters between 1.5 and 1.7 mm; and group C contained subjects with normal CNC diameters between 1.8 and 2.1 mm. Our data revealed a statistically significant difference among the 3 groups when both the intraoperative and 6-month postoperative NRT thresholds were considered at electrodes 1 and 22 but not at electrode 11.

Our data further suggest that a value of 1.5 mm may indeed be appropriate to distinguish between stenotic and normal CNC diameters, as reported by previous authors: on intergroup analysis of electrodes 1 and 22, the NRT thresholds in group A (diameter <1.5 mm) were significantly higher when compared individually to groups B and C (1.5 to 1.7 mm and 1.8 to 2.1 mm, respectively). In other words, stimulation was significantly more difficult below a cutoff value of 1.5 mm.

It has been reported that basal and apical electrodes require lower thresholds and produce higher response amplitudes, an observation that persisted 1 year after cochlear implantation. These observations were recapitulated in the present data, with the apex (ie, corresponding to electrode

**Table 2. Intraoperative and 6-Month Postoperative Neural Response Telemetry Thresholds.**

<table>
<thead>
<tr>
<th>Electrode</th>
<th>Intraoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>188.3</td>
<td>191.9</td>
</tr>
<tr>
<td>Group B</td>
<td>151.1</td>
<td>160.9</td>
</tr>
<tr>
<td>Group C</td>
<td>167.4</td>
<td>166.7</td>
</tr>
<tr>
<td>F</td>
<td>15.98</td>
<td>18.55</td>
</tr>
<tr>
<td>P</td>
<td>&lt;.001b</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Electrode 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>184.6</td>
<td>187.2</td>
</tr>
<tr>
<td>Group B</td>
<td>181.1</td>
<td>176.8</td>
</tr>
<tr>
<td>Group C</td>
<td>176.2</td>
<td>180.4</td>
</tr>
<tr>
<td>F</td>
<td>0.88</td>
<td>1.489</td>
</tr>
<tr>
<td>P</td>
<td>.428</td>
<td>.244</td>
</tr>
<tr>
<td>Electrode 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>188.7</td>
<td>196.8</td>
</tr>
<tr>
<td>Group B</td>
<td>138.4</td>
<td>148.3</td>
</tr>
<tr>
<td>Group C</td>
<td>155.3</td>
<td>159.6</td>
</tr>
<tr>
<td>F</td>
<td>17.08</td>
<td>35.79</td>
</tr>
<tr>
<td>P</td>
<td>&lt;.001b</td>
<td>&lt;.001b</td>
</tr>
</tbody>
</table>

*aExpressed in current level for electrodes 1, 11, and 22 among the 3 groups of patients, compared with analysis of variance. Cochlear nerve canal diameters: group A, <1.5 mm; group B, 1.5-1.7 mm; group C, 1.8-2.1 mm.

*bStatistical significance at Bonferroni-adjusted alpha levels of 0.017 per test (.05/3).
Various explanations may be entertained for the significant difference in NRT thresholds among the 3 groups for electrodes 1 and 22 but not electrode 11. In our opinion, the most likely explanation for this observation is that CNC stenosis may differentially affect the development of cochlear nerve fibers along different points in the cochlea, which may in turn affect the function and development of spiral ganglion cells. It has been suggested that the nerve fiber distribution in the cochlea reaches a maximum of approximately 1400 fibers/mm² at the middle turn of the cochlea, and this may be relatively more robust to derangements in development as compared with the apical and basal turns.

Certain group C patients with normal CNC diameters displayed higher NRT thresholds than did patients in group B, although this did not reach statistical significance. This observation is most likely attributable to chance. However, it is also possible that the pathophysiology of hearing loss in various patients with normal CNC diameters (in our study, groups B and C) is distinct from patients with CNC stenosis (group A), and yet unknown factors may contribute to the observed differences in NRT thresholds.

This study is not without limitations. First, although all patients were noted on MRI to have an intact cochlear nerve, patients were not stratified by quantitative MRI characteristics, including the degree of hypoplasia, if any. Second, patients were not followed longitudinally to compare long-term postimplant performance, although those data are currently being gathered.

Conclusion

NRT thresholds in patients with CNC stenosis—defined as a CNC <1.5 mm in diameter as visualized on cross-sectional imaging—are higher at the base and apex of the cochlea when compared to normal subjects. While NRT is not definitively correlated with postimplant performance, patients with CNC stenosis may require special attention with cochlear implant programming, with implications for preimplant counseling and postimplant performance.

Author Contributions

Shuguang Han, data acquisition, data analysis, manuscript drafting, manuscript approval; Line Wang, study design, manuscript revision, manuscript approval; Daoxing Zhang, data acquisition, data analysis, manuscript revision, manuscript approval; Kevin Peng, study design, manuscript drafting, manuscript approval.

Disclosures

Competing interests: None.

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References


