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Original Article

The effect of the cochlear implant electrode position on the neural response telemetry results: A prospective clinical trial at a single center

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Abstract

Aim: This study aims to investigate the changes in the post-op NRT thresholds of two different implant electrodes of the same brand positioned laterally within the scala tympani, and the pre-modiolar locations, using the same round window approach.

Material and Methods: After CI operation NRT measurements conducted at different times on the Nucleus® CI422 nucleus slim straight and Nucleus® CI24RE electrode types of two different electrode models.

Results: The number of patients who received the Nucleus® CI24RE (ST) electrode and the Nucleus® CI422 nucleus slim straight were 26 (33.3%) and 56 (66.7%), respectively. NRT values tended to decrease from the basal part of cochlea towards an apex at any time of evaluation in both types of cochlear implants.

Conclusion: There was a difference between Nucleus® CI24RE and Nucleus® CI422 nucleus slim straight groups in terms of NRT thresholds. Nucleus® CI422 nucleus slim straight electrode yielded lower NRT threshold levels.

Keywords: Cochlear implant; neural response telemetry.

INTRODUCTION

Cochlear implants are the standard method for rehabilitating hearing loss in patients with severe to profound sensorineural hearing loss (1,2). Intra-op or routine post-op tests, imaging (X-ray or computerized tomography) and audiometric measurements all help to predict the success of a cochlear implant (3).

Various electrophysiological measurement techniques have been used to evaluate the intracochlear position and intraoperative functions of the implant as ECAP (electrically evoked compound action potential), ESRT (electrical stapedial reflex threshold) and IFT (field telemetry). ECAP is the response of the auditory system to electrical stimulation. Neural response telemetry thresholds (NRT), which can be thought as the equivalent of ECAP, provides useful information for an audiologist to determine the dynamic range of each electrode required for the initial programming. This is more useful, especially for pediatric cochlear implants (4,5).

Many factors affect the success of a cochlear implant. One of the most important factors is the placement of the electrode at the right localization within the scala tympani in the cochlea (2,3). Spiral ganglion cells are just located behind the porus medial wall of scala tympani so when the electrode contacts with the modiolus, greater neural responses are achieved at premodiolar locations. On the other hand, two surgical approaches are available for electrode placement; one is cochleostomy, the other is the round window approach. Slim straight electrodes were designed for the round window approach which was thought to preserve residual hearing better, due to minimal drilling of the cochlea, and electrode properties such as contact spread and length (5,6).

This study aims to investigate the changes in the post-op NRT of two different implant electrodes of the same brand positioned laterally within the scala tympani, and the pre-modiolar locations, using the same round window approach.

MATERIAL and METHODS

This retrospective study is based on patient's data with cochlear implants between May 2017 and July 2018 at the

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University of Gaziantep Otorhinolaryngology Department. The evaluated data obtained by NRT measurements conducted during three different postoperative periods (at the first, second and third postoperative programming of the CI processor) on the Nucleus® CI422 nucleus slim straight (lateral wall) and the Nucleus® CI24RE (ST pre-modiolar). The Intraoperative AutoNRT was performed using the Custom Sound Software version 4.4. The postoperative NRT measurements were conducted on three distinctly located electrodes. These are; the 22nd electrode (E22), positioned in the apical region of the cochlea, the 16th and 11th electrodes (E16 and E11) which are positioned in the middle region of the cochlea, and, the 6th and 1st electrodes (E6 and E1) that are positioned in the basal region of the cochlea. NRT's were performed at one, two and six months after the operation on both types of cochlear implants.

Patients who received electrodes which were inserted using the round window approach, for either primary or revision cochlear implantation, met the inclusion criteria for this study.

Surgical procedure: in this research, the same surgeon performed each implantation. An incision of 4-6 cm in length was made on the posterior wall of the external auditory canal at a distance of approximately 1.5 cm. A routine mastoidectomy was performed, and the electrode was placed inside the scala tympani via the round window method using the posterior tympanotomy approach. Postoperative X-ray imaging and the placement of the implant electrodes within the cochlea were documented.
Statistical Method: The normal distribution of numerical data was tested using the Shapiro–Wilk test. The Mann Whitney U Test was used to compare 2 independent groups of variables that did not have a normal distribution. A Friedman two-way analysis of variance was used to compare variables that did not have a normal distribution at different times. The relationship between categorical variables was tested using the Chi-square test. The SPSS 22.0 package software was used for the analyses. $P<0.05$ was accepted as statistically significant.

The ethical committee of the University of Gaziantep approved this study and a signed informed content was taken from all participants with respect to the Declaration of Helsinki Ethical Principles.

RESULTS

A total of 78 patients with cochlear implants were included in this study. The number of patients who received the Nucleus® CI24RE (ST) electrode and the Nucleus® CI422 nucleus slim straight were 26 and 56, respectively. Four patients were excluded who did not meet the inclusion criteria. The CI24RE (ST) was applied to 13 female and 13 male patients, totaling 26 patients, and the CI422 nucleus slim straight was implanted in 19 female and 33 male patients, totaling 52.

The mean age of all 78 patients studied, ranged between 16 and 864 months, with a mean age of 150.44 months ± 203.36 months. Pre-lingual hearing loss was found in 63 patients with the remaining 15 patients suffering from post-lingual hearing loss. The Nucleus® CI422 nucleus slim straight was applied to 41 pre-lingual and 11 post-lingual hearing loss patients. The Nucleus ® CI24RE was implanted in 22 pre-lingual and 4 post-lingual hearing loss patients.

Table 1. Shows the statistical comparison of mean threshold values obtained from NRT measurements conducted on Nucleus® CI24RE (ST pre-modiolar) and Nucleus® CI422 nucleus slim straight electrode types one month after the cohlear implantation

Derivation (Electrode)	N*	Nucleus® CI24RE NRT Thr.	N**	Nucleus® CI422 slim straight NRT Thr.	p VALUE
E22	25	180.00 [171.00-191.00]	49	173.00 [161.00-182.00]	0.047*
E16	25	191.00 [184.00-199.50]	46	167.00 [158.00-178.50]	0.000*
E11	26	196.50 [185.00-205.25]	48	173.00 [161.75-191.00]	0.000*
E6	26	196.00 [187.75-208.00]	41	184.00 [179.00-195.00]	0.001*
E1	23	199.00 [191.00-214.00]	47	185.00 [178.00-196.00]	0.000*

Abbreviations: N: Number of patients.
N* : Number of (Nucleus® CI24RE)
N**: Number of (Nucleus® CI422 slim straight)

Table 2. Displays the statistical comparison of threshold values obtained from NRT measurements conducted on Nucleus® CI24RE (ST pre-modiolar) and Nucleus® CI422 nucleus slim straight electrode types two months after the cohlear implantation

Derivation (Electrode)	N*	Nucleus® CI24RE NRT Thr.	N**	Nucleus® CI422 slim straight NRT Thr.	p VALUE
E22	25	173.00 [163.00-187.00]	38	168.00 [157.50-179.00]	0.121
E16	25	182.00 [170.00-193.00]	36	159.50 [152.75-169.25]	0.000*
E11	26	185.00 [172.75-197.00]	37	173.00 [163.00-182.00]	0.002*
E6	26	185.00 [182.00-202.00]	33	179.00 [171.50-185.00]	0.001*
E1	23	194.00 [185.50-204.00]	35	179.00 [170.00-191.00]	0.002*

Abbreviations: N: Number of patients.
N* : Number of (Nucleus® CI24RE)
N**: Number of (Nucleus® CI422 slim straight)

Three tables were created with the threshold values obtained from NRT measurements of different CI at different times. Table 1 represents the NRT values 1 month after the operation. Table 2 displays the same value 2 months after the operation and Table 3 represents the NRT values 6 months after the operation. The NRT's displayed with mean values, include minimum and maximum threshold values in all three tables respectively.

Considering the depth of data, NRT tended to decrease from the basal part of cochlea towards an apex at any

time of evaluation. A decreasing NRT of each electrode was noted in the sixth postoperative month period when compared to the first month's NRT. Besides, significantly lower postoperative NRT were observed for Nucleus® CI422 SS vs Nucleus® CI24RE at every type of electrode at different times.

Table 3. Demonstrates the statistical comparison of threshold values obtained from NRT measurements conducted on Nucleus® CI24RE (ST pre-modiolar) and Nucleus® CI422 nucleus slim straight electrode types six months after the cohlear implantation

Derivation (Electrode)	N*	Nucleus® CI24RE NRT Thr.	N**	Nucleus® CI422 slim straight NRT Thr.	p VALUE
E22	10	170.00 [167.25-181.75]	21	170.00 [164.00-184.50]	0.603
E16	9	186.00 [172.00-194.00]	21	160.00 [155.00-180.50]	0.012*
E11	9	186.00 [173.00-203.00]	19	168.00 [161.00-182.00]	0.014*
E6	10	190.50 [176.00-205.70]	16	178.50 [173.50-185.00]	0.053
E1	8	196.50 [182.75-205.25]	18	182.00 [175.25-185.00]	0.013*

Abbreviations: N: Number of patients.
N*: Number of (Nucleus® CI24RE)
N**: Number of (Nucleus® CI422 slim straight)

Table 4. NRT values of each electrodes at diverse periods

Electrode	Implant Type	NRT Values*	p VALUE*
E22	Nucleus® CI24RE	180.00- 173.00- 170.00	0.016*
E22	Nucleus® CI422 SS	173.00-168.00-170.00	0.022*
E16	Nucleus® CI24RE	191.00-182.00-186.00	0.015*
E16	Nucleus® CI422 SS	167.00-159.50-160.00	0.011*
E11	Nucleus® CI24RE	196.50- 185.00-186.00	0.105
E11	Nucleus® CI422 SS	173.00- 173.00- 168.00	0.193
E6	Nucleus® CI24RE	196.00-185.00-190.50	0.497
E6	Nucleus® CI422 SS	184.00-179.00-178.50	0.009*
E1	Nucleus® CI24RE	199.00-194.00-196.50	0.010*
E1	Nucleus® CI422 SS	185.00-179.00-182.00	0.016*

NRT Values* : Mean values at the first , second and six months after operation respectively

On another dimension, a comparison of NRT's was made among the different types of implants from each electrode. Their statistical significance, which was performed at three separate times, (first, second and sixth month after the operation) are shown in Table 4. The P values shown in Table 4 were obtained from the comparison of the mean NRT's of each electrode that was taken from Table 1, Table 2 and Table 3.

DISCUSSION

Three factors that determine the position of the electrode within the cochlea: the morphology of the cochlea, electrode design and the insertion technique of the surgeon (1,2,4).The electrode position of the CI (cochlear implant) is essential for providing hearing preservation surgery (5). In contrast to electrodes placed in the scala tympani, the insertion of scala vestibuli negatively affects auditory and speech performance after CI surgery (3,7,8).

This study aims to interpret the transformation of NRT in the 6 months after the CI operation with the different intracochlear placement of electrodes. In this study, the evaluations of the changing NRT's of two different types of CI electrodes were compared over two parameters. These are evaluation time and electrode location.

In this study, the researchers found that the highest NRT among the electrodes was seen in the E1 electrode bundle of the Nucleus CI422 SS in the first month. Additionally, the E1 electrode bundle of the Nucleus CI24RE had a higher value than the other electrodes of the same CI at a different time of evaluation. This finding is thought to be related to the amount of interfacing between the electrodes and spiral ganglion cells. This interface is broad at the basal part and narrow at the apical part of the cochlea (9-11). Furthermore, the progressive adherence pattern of conductive molecules in the apical region may result in a lower NRT (12). In the literature, electrodes which are located in the apical part of the cochlea were also found to have lower NRT, similar to this current study's findings (11,13).

In the slim straight CI and the premodiolar CI, the electrodes located in the middle region did not display any differences in terms of the NRT's shown in previous studies (10,14). However, the basal electrodes of slim straight NRT's were lower in this study. This finding could be related to round window insertion, intracochlear position and activation of slim straight electrodes. Previous reports argued that the slim straight was particularly suitable for round window insertion and this approach is believed to allow lower rates of cochlear trauma due to minimized drilling (6).

The type of the electrode is another factor which also affects the electro-neural relation (15). It is known that a perimodiolar electrode contributes to obtaining a high NRT response (16-18). Higher NRT's are seen when the distance between the modiolus and the electrodes increases (18,19). According to our findings; there is a discrepancy in the premodiolar electrode location that yielded a high NRT. The activated parts of the slim straight CI electrode are just located on one side. However, the premodiolar electrode activates circumferentially which may result in higher NRT with a closer modiolus location (18,20). Regardless of the electrode location, NRT's tend to decrease progressively in the second and sixth months after the initial assessment. Previous reports had a similar finding because of fibrous tissue formation around the electrode array. Additionally, the electrode-fluid interface

could also change the electrochemical structure of the electrode array. (9,13,21) Six months after the first stimulation of CI, NRT's were found to be stable and this stabilization persists throughout the first and second year after the operation. (13,21-23)

One of the limitations of this study is that it did not evaluate the insertion depth angle of CI or diameter of cochlea postoperatively. However, a previous report concluded that the insertion depth angle and diameter of the cochlea did not have a statistically significant effect on NRT. (24) Another limitation was not searching the NRT's of CI to evaluate residual hearing preservation. Only patients who did not benefit from hearing devices for at least 6 months for severe-profound hearing loss could be selected for cochlear implantation in the study region. The correlation of the NRT and hearing assessment is beyond the scope of this article. Additionally, the researchers performed cochlear implantation using the round window approach with a single surgeon and were not able to compare the NRT changes with a distinct surgical approach.

CONCLUSION

This current study revealed that there was a difference between the Nucleus® CI24RE and the Nucleus® CI422 nucleus slim straight groups in terms of NRT. The Nucleus® CI422 nucleus slim straight electrode yielded lower NRT levels. As a result, this study concludes that the cochlear location of the electrode is a factor that influences NRT.

Competing interests: The authors declare that they have no competing interest.
Financial Disclosure: There are no financial supports.
Ethical approval: This study was approved by the Institutional Ethics Committee and conducted in compliance with the ethical principles according to the Declaration of Helsinki.

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