ORIGINAL ARTICLE

Comparison of Neural Response Telemetry and Electrical Stapedius Reflexes with Behavioral Thresholds in Cochlear Implant Users

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Abstract

Objective: The present study aimed to compare neural response telemetry (NRT) and electrical stapedius reflex (ESR) with behavioral thresholds in pre- and post-lingual cochlear implant (CI) recipients. **Materials and Methods:** A total of 30 patients (15 males and 15 females) aged 3–40 years old were participated in this study. They were underwent CI operation at Khuzestan CI, Ahvaz, Iran, from March 2013 to August 2016. The NRT and ESR values were measured in all patients and compared with the respective behavioral threshold at the same time. **Results:** The NRT and ESR thresholds were determined successfully in all patients. The NRT thresholds showed significant correlation with the C-levels ($r = 0.645$, $P < 0.001$) and fell at 74.12% of the dynamic range of the map in children and at 85% in adults. Our data indicated that there was a strong correlation between the mean ESR and behavioral thresholds (C-levels) in children ($r = 0.78$, $P = 0.004$) and adults ($r = 0.82$, $P < 0.001$). The mean behavioral thresholds were identical between males and females (independent sample *t*-test, $P > 0.05$). In addition, both NRT and ESR showed no statistical difference between males and females (independent sample *t*-test, $P > 0.05$). **Conclusion:** Both ESR and NRT thresholds showed strong correlation with the respective behavioral thresholds; however, the ESR threshold may be a better predictor of C-levels values compared with the NRT thresholds.

Key words: Cochlear implant, electrical stapedius reflexes, neural response telemetry

INTRODUCTION

Different methods have been proposed for objective measurement of the neural responses in cochlear implant (CI) patients including electrical stapedius muscle reflex (ESR), electrical evoked auditory brain stem response (EABR), and neural response telemetry (NRT). These methods could provide useful information on the integrity of the CI system for efficient programming of speech processor.[1,2] These approaches enable the users, which most of them are children, to choose their desired speech processor settings.[3,4] The main purpose of a CI sound processor programming is to provide convenient and appropriate stimuli for the recipients of cochlear neuroprosthesis and usually is achieved through certain electrophysiological measurements.[5]

NRT is a quick and non-invasive method for the measurement of evoked compound action potential thresholds from the auditory nerve using the CI.[6] This approach applies an electrical pulse to a specific intracochlear electrode, and the evoked neural responses are recorded at the neighboring electrodes. Then, the measured evoked potentials, probably originating from the proximal part of the auditory nerve, were clinically analyzed. In NRT, radiotelemetry is utilized to measure auditory nerve action potentials. This method

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has several advantages over EABR. First, NRT requires a shorter collection time which is of essential significance for intraoperative use. Second, there is little need for sophisticated instruments or patient cooperation, as NRT uses the CI for both stimulating and recording potentials. In addition, EABR is primarily associated with false stimulation responses and can be normally intraoperatively recorded. Using NRT, post-operative data can be compared to intraoperative data. Moreover, NRT can be used to predict the behavioral threshold (T-levels) and maximum comfort levels (C-levels) to build stimulation maps for the CI patient and facilitate the postsurgical rehabilitation process.[7-10]

ESR refers to contractions of the stapedius muscle in response to high-intensity electrical stimuli.[11] ESR is a quick and non-invasive method to verify the integrity of auditory nerve functions.[12] ESR thresholds could be used to extract useful information, as several studies have indicated an association between these thresholds and the assessment of maximum comfort level (C-level) in adults and children with CIs.[13-16]

The correlation between the values obtained objectively and values assessed by the behavioral method has been extensively investigated. However, in clinical practice, there is no consensus regarding the efficacy of these measures for the CI users. The present study aimed to compare NRT and ESR thresholds with behaviorally measured comfort levels in CI recipients.

MATERIALS AND METHODS

This was a cross-sectional study conducted on 30 patients (15 males and 15 females) aged between 3 and 40 years old. All patients were operated at Khuzestan CI, Ahvaz, Iran, and received their Nucleus Freedom CI prosthesis between March 2013 and August 2016. Mean time of auditory deprivation was 3.26 years (range: 7 months–5 years). All subjects had full electrode insertion and reported any history of systemic diseases, middle ear infection, or ear malformations. Patients with poor cooperation during behavioral measurements were excluded from the study.

The protocols and all experimental procedures of the study were approved by the local Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (AJUMS), Ahvaz, Iran (registration code: IR.Ajums.REC.1396.1069), which were in complete agreement with the ethical regulations of human studies set by the Helsinki Declaration (2014).

Intra- and post-operative NRT and ESR tests were performed on all patients undergoing CI to examine the CI system and facilitate speech processor programming. In the NRT, the auditory nerve compound action potential threshold was measured using Nucleus® (Australia) CIs. Intraoperative ESR was measured visually and post-operative ESR was measured in the opposite ear using an AT235 middle ear analyzer (Interacoustics Co., Denmark). In addition to NRT and ESR tests, the behavioral thresholds (T-levels) and maximum comfort levels (C-levels) of each patient were recorded.

Data were analyzed with Statistical Package for the Social Sciences (version 22, Windows) using descriptive statistics including frequency distribution tables, and numerical diagrams and indicators. Independent *t*-test or, if necessary, its non-parametric equivalent was used to compare the means of variables. Pearson correlation coefficient or, if necessary, its non-parametric equivalent was used to determine the relationship between variables. For all statistical analyses, the significance level of 0.05 was considered.

RESULTS

The mean pre- and post-lingual for NRT and ESR measures and the respective independent-samples test for the participants are presented in Table 1. The mean pre- and post-lingual C-levels were obtained at 192 and 190, respectively (paired sample *t*-test, $P > 0.05$). Furthermore, the average of pre- and post-lingual T-levels was 159 and 152, respectively (paired sample *t*-test, $P > 0.05$) [Table 1].

The mean pre- and post-lingual NRT was 159.9 and 155.3, respectively (paired sample *t*-test, $P > 0.05$), demonstrating no statistically difference between both groups.

The mean behavioral threshold of pre- and post-lingual CI users was identical among males and females (independent sample *t*-test, $P > 0.05$). In addition, we found no statistical difference was found between the means of any of the NRT and ESR between males and females (independent sample *t*-test, $P > 0.05$) [Table 1].

The NRT thresholds and the ESR thresholds were obtained successfully in every patient, and C-levels were recorded in all adult cases. The NRT thresholds were always lower than the ESR thresholds in the children and lower than the ESR threshold and the C-level in the adults for a given electrode under test. It was possible to record reliable NRT responses in 89% of activated electrodes. The correlation between the mean ESRs and the behavioral thresholds of all pre- and post-lingual CI users is presented in Table 2. The findings suggested that NRT thresholds are significantly correlated to the C-levels ($r = 0.645$, $P < 0.001$) and fell at 74.12% of the dynamic range of the map in children and at 85% in adults.

In the stage, the correlation between the mean NRT and the behavioral thresholds of all pre- and post-lingual CI users is calculated [Table 3]. The mean ESR threshold was 91.45% of the mean C-level for all electrodes combined. The mean ESR thresholds for the electrodes tested varied from 88.2% to 95.1% of the C-level [Table 3]. Our data indicated that there was a strong correlation between the mean ESR

and behavioral thresholds (C-levels) in children (r = 0.78, P = 0.004) and adults (r = 0.82, P < 0.001). These results show that the ESR threshold may be a better predictor of C-levels values than NRT thresholds [Table 3].

As it could be seen in Table 3, the ESR values are correlated with T behavioral thresholds and are statistically reliable.

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The correlation analysis showed that the NRT values are correlated with C behavioral thresholds and are statistically reliable [Table 3]. As can be seen, NRT values are correlated with T behavioral thresholds and are statistically reliable [Table 3].

Given the specified *P*-values, the mean pre- and post-lingual NRT and ESR values are similar.

DISCUSSION

The performance of individuals with a CI can vary to a great extent.[17] One of the most important variables that can affect the subject's performance is the presentation of electrical stimulation from the CI device to the auditory nerve. The activity of the auditory system pathways can be recorded through auditory evoked potentials.[18] These potentials are a superposition of many small electrical impulses generated by the 8th nerve in response to the presentation of an electrical stimulus.[19,20]

In the current study, NRT was satisfactorily recorded by means of the telemetry system during the CI operation. NRT is an easy and quick method used to measure responses of auditory nerve following electrical stimulation.[21-23] It also can be used to check the integrity of the electrode chain when it is inserted in the cochlea. NRT had advantage relative to EABR, because it does not need external electrodes placed on the head surface, it is less susceptible to myogenic interference and needs a smaller number of stimuli to be triggered. Given that they are measured directly from intracochlear electrodes, NRT amplitude tends to be greater than that of other electrical potentials.[24-26]

In the present study, we examined the relationship between NRT and ESR with behavioral threshold in 30 CI users in the age range of 3–40 years. Our results indicated a good correlation between NRT and ESR with behavioral loudness levels. Nardo *et al*.[25] studied the relationship between NRT and behavioral threshold in 12 CI users of the Nucleus® 24 prosthesis (6 females and 6 males) with a mean age of 22.4 years. The results pointed out a good correlation between NRT and behavioral thresholds. They concluded that NRT offers valuable information on the auditory nerve

Table 1: The mean pre- and post-lingual NRT and ESR and the independent-samples test for the participants

Variable	Levene's test for equality of variances		*t*-test for equality of means						
	F	Sig.	t	df	Sig. (two-tailed)	Mean difference	SE difference	95% confidence interval	
								Lower	Upper
NRT									
Equal variances assumed	2.247	0.138	1.106	78	0.272	3.53822	3.19882	–2.83014	9.90658
Equal variances not assumed			1.106	73.108	0.272	3.53822	3.19882	–2.83686	9.91329
ERT									
Equal variances assumed	0.479	0.491	1.698	78	0.093	5.88646	3.46628	–1.01437	12.78729
Equal variances not assumed			1.698	76.978	0.094	5.88646	3.46628	–1.01581	12.78874

Table 2: The correlation between the mean ESR and behavioral thresholds of all pre- and post-lingual CI users

Variable	ESRpre	Cpre	Tpre	ESRpost	Cpost	Tpost
ESRpre	1	0.509	0.814	-	-	-
Cpre	0.509	1	-	-	-	-
Tpre	0.814	-	-	-	-	-
ESRpost	-	-	-	1	0.513	0.706
Cpost	-	-	-	0.513	1	-
Tpost	-	-	1	0.706	-	1

Table 3: The correlation between the mean NRT and behavioral thresholds of all pre- and post-lingual CI users

Variable	NRTpre	Cpre	Tpre	NRTpost	Cpost	Tpost
NRTpre	1	0.669	0.683	-	-	-
Cpre	0.669	1	-	-	-	-
Tpre	0.683	-	-	-	-	-
NRTpost	-	-	-	1	0.732	0.480
Cpost	-	-	-	0.732	1	-
Tpost	-	-	1	0.480	-	1

integrity and proper CI performance. Dees *et al*.[27] also investigated post-operative NRT in 140 CI recipients from 13 European countries in which 96% of patients underwent NRT. Their results indicated that hearing impairment had a little influence on NRT characteristics. However, age greatly influenced NRT properties, with the age range of 15–30 years accounting for the highest effect.

In the present study, a strong relationship was found between the ESR and behavioral thresholds (C-levels) in children and adults. Stephan and Welzl-Müller[28] investigated the ESR threshold and the C-levels recorded in units of current in five adult CI users. The high correlation between ESR and C-level values (0.92) suggesting the usefulness of the ESR threshold in determining comfortable levels. Similar results were achieved by Polak *et al*.[29,30] in post-lingually and pre-lingually deafened users of the nucleus 24 implant system ($r = 0.93$ and $r = 0.95$, respectively).

Polak *et al*.[30] examined the relationship between NRT and ESR with behavioral threshold in CI users. Results indicated that both NRT and ESR could equally contribute to speech processor adjustment. Similarly, the present study pointed to a correlation between the mean ESR and behavioral threshold of male/female pre- and post-lingual CI users. Polak *et al*.[31] studied the relationship between NRT and ESR with behavioral threshold in two groups of post-lingually and pre-lingually deafened adult CI users. The results revealed that the estimation of behavioral threshold using NRT and ESR requires different correction factors for pre-lingually versus post-lingually deafened adults. In a similar vein, the present study pointed out a correlation between the mean NRT and behavioral threshold of male/female pre- and post-lingual CI users. Walkowiak *et al*.[13] investigated the relationship between NRT and ESR in speech processor programming of CI users. The results showed that although ESR is a good indicator for estimating the auditory comfort threshold, and both NRT and ESR can be useful tools for adjusting and programming speech processors for children.

CONCLUSION

The results showed that although ESR is a good indicator for estimating the auditory comfort threshold, both NRT and ESR can be useful tools for adjusting and programming speech processors for children.

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