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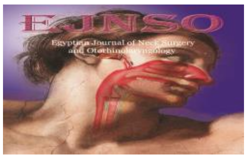

Correlation between cochlear nerve size and outcome of cochlear implant

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Abstract:

Introductions: Cochlear implantation is an effective treatment method for severe to profound hearing loss. Many factors that may influence cochlear implantation success, one of them is the size of cochlear nerve.

Objective: To evaluate the effect of cochlear nerve size on cochlear implant outcome in children.

Methods: 30 children with age range from 1-6 years. All of them were implanted with cochlear implant of MEDEL device, sonata II (Med-EL, Innsbruck, Austria). The thickness of cochlear nerve was measured by axial and coronal three-dimension magnetic resonance images. Postoperative auditory evaluations were performed in the form of pure tone evaluation, littlEars Arabic Questionnaire and speech and language development assessed by Age of first detection of sound, age of first spoken word and electrophysiological by ECAP. Correlation between cochlear nerve thickness, and postoperative auditory perception was analyzed to determine whether variation in size of normal cochlear nerve size affect postoperative outcome of cochlear implant.

Results: The mean of thickness of the cochlear nerve was 1.07 mm 0.02 , of pure tone threshold was 24.38 dBHL,of LittleEARs score was 25.53, ECAP threshold was7.09 .The correlation between the thickness of cochlear nerve and average aided threshold, ECAP is negative and statistically non-significant, positive and non-statically significant correlation with the first detected age. On the other hand, nerve thickness found to positive and significant correlate with little EARs score (p=0.05).

Conclusion: The thickness of nerve is not significantly affecting post operative outcome of cochlear implant in patient neither nerve was aplastic nor hypoplastic.

Keywords: Cochlear, Implant, Outcome, Nerve

Introduction

A successful therapeutic option for individuals with severe to profound hearing loss is cochlear implantation, involves sending signals to the spiral ganglion's neurons, which then allows the impulses to be sent to cochlear nerve. Normal or close to normal speech and language abilities in prelingually deaf kids and achievement of normal hearing in post lingually deaf persons are the main goals of cochlear implantation. However, the anticipated results could vary based on personal characteristics as well as post-implantation instruction and training. [1-3]

Several factors that may impact the result of a cochlear implantation have been studied in earlier studies.[4,5] Some of the variables that typically influence these variations: the cochlear nerve,

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residual hearing, age at implantation, hearing loss onset, duration of hearing loss, inner ear's normal anatomy, parental participation, the best time to utilize the cochlear implant audio processor each day, and cognitive abilities. [6-9]

As there is now no good way to anticipate the outcomes of cochlear implants, candidates should be carefully examined. Due to their incredibly varied outcomes, well-studied illnesses such malformations of cochlea, abnormalities of cochlear nerve, cochlear ossification may have a higher likelihood of a bad prognosis. [10-12] Among these defects, cochlear nerve anomalies are among the most challenging. Abnormalities of the cochlear nerve have long been diagnosed using high resolution MRI. Numerous studies have measured the cochlear nerve's diameter. Greater success after surgery was linked to larger cochlear nerves. Cochlear implant candidates' cochlear nerve diameters were assessed by Morita et al. using axial magnetic resonance imaging (MRI).[13]

But when parasagittal MRI measurements were taken in independent tests, more accurate results were obtained. [14,15] In children with profound hearing loss on MRI, Russo et al. discovered mild hypoplasia of the cochlear nerve.[16] In research done by Chung and colleagues, they found that after cochlear implantation, people with a thin bony cochlear nerve canal or a loss in cochlear nerve function were not functioning effectively.[17]

However, little is known about how variations in cochlear nerve size in patients who are not hypoplastic can affect postoperative cochlear implant performance. **Kim et al**., [18] noticed positive correlation between the cross-sectional area of the cochlear nerve and auditory performance in post lingually deaf patients with cochlear implant. Even in the presence of hypoplastic cochlear nerves, cochlear implants are still beneficial for patients and better audiological outcome associated with absence of other abnormalities. [19] Therefore, the aim of this study was to evaluate the size of the cochlear nerves that appeared to be normal in children who underwent cochlear implants and investigate any possible correlation among size of cochlear nerve and postoperative performance that might be helpful in forecasting cochlear implant outcomes.

Aim of work:

To study the cochlear nerve size effect on CI outcome in children.

Materials and Methods:

Ethical consideration:

The parents or the designated caregiver for the children gave their informed written consent. Sohag University Faculty of Medicine's Medical Research Ethics Committee gave the project approval.

Participants:

It was prospective research including thirty child who had prelingual, bilateral severe to profound degree hearing loss with the following inclusion criteria: ages ranged from 1 to 6 years old,the child's cochlear nerve wasplastic and not hypoplastic when compared to the fascial nerve in an MRI, free of cochlear ossification, normal inner ear development and growth and, the following exclusion criteria participants with cognitive or learning disabilities were removed. Every child was implanted with a MED-EL device, sonata II (Med-El, Innsbruck, Austria) at Sohag University Hospital had implanted in the period from September 2019 to September 2020.

Measurements and imaging of the cochlear nerve

All children underwent radiological evaluation by CT on temporal bone then MRI of the cochlea and internal auditory canal performed in accordance with the following protocol: patient is lying down in a supine neutral position, an MRI was performed using a 1.5 T MRI device (Philips, Acheiva, Netherlands) with a dedicated head coil. The protocol consisted of the subsequent sequences: balanced turbo gradient echo (B TFE sense) sequences , axial and coronal three- dimension (3D) on cerebellopontine angle (CPA) (scan duration is 1.43 min for axial and 1.35 min for coronal ,TR equals six ms, TE equals three ms, the field of view is 180 mm, slice thickness is 1 mm and interslice gap is 0.5 mm, flip angle is sixty degrees, , sagittal oblique T2 weighted 3D Drive evident sequence perpendicular on both sides of the internal auditory canal (IAC). scan period is 2.26 min, TR is 1.5 s, TE is 250 ms, FOV is 130 mm, slice thickness is 1.4 mm, interslice gap is 0.7 mm, flip angle Equal 90°), FLAIR images of the brain (scan duration is 3 min, TR is 9 s, TE is 140 ms, FOV is 230 mm, slice thickness is 4 mm, interslice interval is 1 mm, flip angle is 90°).

Using OsiriX software and reformatted sagittal oblique images, the cochlear nerves of thirty patients were measured. Figures display the cochlear nerve's diameter and the nerve signal reformatted image (Fig. 1).

Outcome measures*:*

Audiological evaluation: Included pure tone audiometry, which was done in a sound-treated room. The participant's 45-degree azimuth was used to measure the pure tone threshold at 4 different frequencies: 500 Hz, 1 kHz, 2 kHz, and 4 kHz.

The LittlEars Auditory Questionnaire is a parent survey created to evaluate the auditory behavior of children with hearing loss who receive a cochlear implant or hearing aid before they become 24 months old. It documents the preverbal auditory development of the kid in their natural surroundings during the first two years of hearing. This LittlEARS1 Auditory Questionnaire has 35 "yes/no" items designed to evaluate the observable receptive, semantic, and early expressive language skills of very young children in response to auditory stimuli. We use the Arabic version, which was designed by MED-EL, to track the preoperative and postoperative auditory development of children with CI. It was completed at the end of the first year following activation 20 .

Also, speech and language development were examined by assessment the time of 1st detected sound, 1st spoken word post cochlear implantation surgery as observed by the parents.

Measurements of electrically evoked compound action potentials (ECAP):

A MAX Interface Box (V1.0.0/V1.1.2) and a MAX Coil S were used to link the CI to the MAESTRO software (MED-EL, Innsbruck, Austria, version 9.0.4). The quantity of successfully recorded ECAP responses at each electrode (E1–E12) in this investigation. If an ECAP response was recorded at each of the 12 electrodes, the ECAP was deemed successful. For each individual in the analysis, ECAP thresholds were averaged over all 12 electrodes, and cochlear nerve stimulation was usually dispersed over all 12 electrodes.

Data analysis:

The SPSS computer program version 22.0 was used to analyze the data. Means ± standard deviation was used to express quantitative data. The data was evaluated for normality using the Kolmogorov-Smirnov test, which was negligible, indicating that parametric tests were used since the data was normally distributed. The data was analyzed using Repeated Measure ANOVA and the paired sample t-test. The Chi-square (X2) test was employed to compare qualitative variables. In all statistical tests employed in the study, a threshold of significance of 0.05% was adopted.

Results

The present study was conducted on 30 cochlear implant children. Their age ranged between 1 to 6 years old, 14 males and 16 females.

The mean of nerve thickness in our study group was 1.07±0.02, with range from 1.00 to 1.13. Mean of average Aided threshold was 24.38±6.91, mean of average ECAP was 7.09±7.96, mean of average threshold level was 8.31±6.20, and mean of first detected word in the study group was 4±1.154 months, with range from 2 to 6 months. Mean of first spoken word was 7.03±2.6 months; mean of little EARs was 25.53±6.09 with range 11 to 34 (Table 1)

Correlation between Nerve thickness and average aided threshold, ECAP, T level and C level and 1st detected, 1st spoken word and Little Ears: nerve thickness is in negatively and non-statistically significant correlation with each of average aided PTA threshold, ECAP threshold, nerve thickness is in negatively and non-statistically significant correlation with 1st spoken age, but positive correlate with 1st detected age, on the other hand, nerve thickness found to positive and significant correlate with Little EARs score (p=0.05)(Table 2).

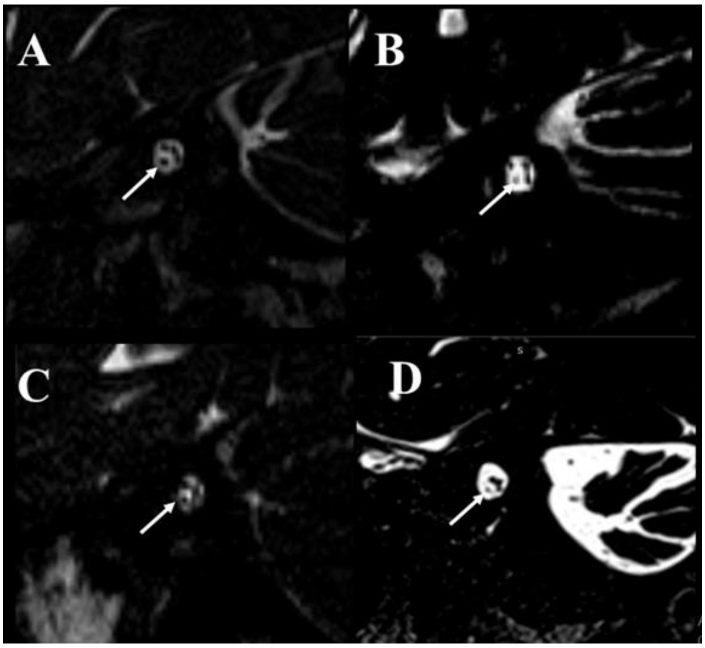

Fig.1. Sagittal oblique MRI image in four different patients with variable cochlear nerve thickness and signal pattern. (A) Normal nerve thickness and normal low signal (arrow), (B) Normal nerve thickness but abnormal medium-high signal (arrow), (C) Reduced nerve thickness with normal low signal (arrow), (D) Reduced nerve thickness with abnormal medium-high signal (arrow).

Table (1):

	Average Nerve thickness in mm	Average Aided threshold in dB	Average ECAP Threshold in qu	1st Detected word (months)	1st Spoken word (months)	Little Ears
Mean +/-SD	1.07+/-0.02	24.38+/-6.91	7.09+/-25.96	4 +/-1.145	7.03+/-2.63	25.53 +/-6.09
Range	1:1.3	14.16:39.16	2.87 :48.51	2 :6	3 :12	11 :34

Table (2):

		Average Aided threshold	Average ECAP	1st Detected (months)	1st Spoken (months)	Little Ears
Average nerve thickness	Pearsons's correlation	-0.23	-0.001	0.023	-0.22	0.35
	P- Value	0.2	0.99	0.9	0.23	0.05

Discussion:

Cochlear implantation can be a viable treatment for prelingual profound hearing loss. However, there is a wide range in cochlear implantation outcomes. [3] Anatomical issues related to kinds of inner ear abnormalities are among the things that greatly impact how well cochlear implants work. [21,22] The size of the cochlear nerve may have an impact on the postoperative rehabilitation process. Thus, the purpose of this study was to examine the relationship between the auditory nerve's size and the outcome of the cochlear implant.

In order to predict the results of cochlear implant procedure, an extensive evaluation of the patient is required prior to the procedure. This evaluation includes computed tomography (CT) and magnetic resonance imaging (MRI) of the temporal bone. Although CT scans can reveal nerves inside the internal auditory canal, they are not very useful for identifying the osseous bones of inner ear. [23] On the other hand, MRI can be a very useful tool for cochlear implant candidates to see their brain and nerve systems. Clinical professionals shouldn't depend solely on findings of CT for inner ear morphology because patients who have normal diameter of internal acoustic canal on CT scans have absent cochlear nerves on MRIs. [23] For these reasons, an MRI should be used to assess the auditory nerve's morphology by its measurement in millimeter or by comparing the size against the facial nerve. [24]

Numerous studies have employed radiologic examination to measure the cochlear nerve's size in both persons with normal hearing and in different patient groups. Lou et al. examined impact of age on size of cochlear nerve among children with normal hearing by using 3-T MRI to evaluate the cochlear nerve at three different measurement sites. They discovered that the nerve's highest value was in the middle of the IAC and that its size remained constant with age. [25] **Herman et al. 2011** estimated the cochlear nerve's cross-sectional area in individuals with postlingual deafness and normal hearing by using MRI. They found that parasagital CISS MRI was a valid method for measuring the cochlear nerve. They discovered that the deaf patients' CSA was much lower than individual with normal hearing. [26] Using high-resolution MRI to assess size of cochlear nerve in kids with sensorineural hearing loss and normal hearing, **Russo et al. , 2006** discovered that individuals with profound hearing loss had somewhat hypoplastic cochlear nerves. They came to the conclusion that high resolution MRI could be used to quantify the auditory nerve precisely. [27] We also assessed the cochlear nerve's size using high quality MRI. When the criterion implied that cochlear nerve is marginally larger than facial nerve and this may be employed in the determination of anomalies of cochlear nerve presented by **Miyasaka et al. ,2010** , we included patients whom cochlear nerve have normal size and normally appearing. [24] In earlier research, the facial nerve was a reliable reference for evaluating the cochlear nerve in patients with hearing loss. [28]

Cochlear nerve was visualized and measurements were made using the axial, coronal, parasagittal reformatted pictures in this investigation. The purpose of this study is to look at the correlation between the size of the cochlear nerve and the outcome of CI. Within the range of 1.00 to 1.13mm, the mean nerve thickness in our study group was 1.07mm± 0.028mm. The mean nerve thickness in the inner ears was determined to be 1.58 mm in a study by **Change et al., 2018** [17]; similar results were observed by other researchers who reported mean nerve thicknesses of 1.12 mm and 1.0 mm 28–29. Furthermore, there was no variation in nerve diameter and CSA between age and gender. As the pediatric population continues to develop and grow, there is concern for the cochlear with age increases. Nonetheless, research on embryology revealed that the vestibulocochlear nerve was fully formed by the sixth embryonic stage and remained unchanged as the body developed. [29] Since age has no influence on the cochlear nerve's width, we did not split the patients in our study based on age.

Mean of 1st detected age of 1st detection of sound in our study group was 4±1.1 months, with range from 2 to 6 months. Mean age of 1st spoken word was 7.03±2.6 months. The mean Aided threshold was 24.38 dBHL. The EARS assessment tool assesses the evolution of auditory perception after cochlear implantation, offers guidance for device fitting, and serves as a tool for the ongoing evaluation of children who have received cochlear implants. [29] Numerous prior investigations assessing the development of auditory perception in the same patient group employed the EARS instrument. [30] Additionally, patients in dissimilar age groups [31] or patients in the similar age group but in distinct groups with different etiologic causes for hearing loss were compared using this technique.[32] Even while dissimilar age groups and etiologic causes for hearing loss show distinct recovery charts, auditory perception generally progresses over time after implantation and rehabilitation, and this progress happens steadily at intervals of six months or a year. [29] Additionally, the research showed that the auditory responses improved with earlier implantation. [30]

We used the EARS assessment instrument to evaluate our patients for our study. When we used the EARS assessment instrument to analyze the children in our study at the end of the first year following implantation, we discovered that the mean of the little EARs was 25.53±6.09 with a range11-34.

We evaluated the CN's functional state using ECAP metrics. Previous studies have assessed the relationship between CI outcomes and each of these ECAP measures. These studies' overall findings were mixed. For instance, some research found that CI users who recovered from refractoriness more quickly or steeply had higher speech perception scores. [34] Other studies did not find these associations. [35] Table 1 show that ECAP was 7.09qu. Additionally, the correlation between nerve thickness and the average ECAP was found to be statistically not significant and negatively. Also, in 2023 **Leonhard et al. 2023** found that the cross-sectional diameter of the cochlear nerve and the ECAP measurements for ART and Auto ART did not significantly correlate. They stated that the ECAP threshold and the ECAP slope cannot be predicted by MRI images, nor can a thicker or thinner CN produce either. Given that the CN CSA and the number of SGCs are directly correlated, it would be valuable to look into any potential connections between the CN CSA and the SGC population in these people.[36]

According to our research, nerve thickness and aided threshold, or ECAP, have a non-significant negative correlation. **Gozen et al. 2022** [37] discovered that nerve diameter was not significantly correlated with postoperative audiologic performance, which is similar to our findings. Furthermore, **Chung, Jang, et al. (2018)** attempted to compute the link between nerve thickness and a number of post-CI speaking ability measures, such as the threshold level outcomes, open-set word or phrase score, and CAP score. The breadth of the BCNC did not substantially correlate with the CAP score 24- or 36-months following CI. These results show that preoperative CT scan measurements of the BCNC width may be related to post-CI outcomes. [17]

While cochlear nerve size has been a focus of numerous radiological investigations, nothing is known about how cochlear nerve size affects implant success in children who are prelingually deaf. In the current study, nerve thickness was found to have a positive and significant link with Little EARs score (p=0.05), but a non-significant negative correlation with first spoken word age and a positive correlation with first recognized sound age. This agrees with the results of (Chung, Jang, et al. 2018), who found that nerve thickness and EARs score had a positive correlation. [38]

Gozon et al. 2022 found that MTP test responses grew over time, with high scores on the first month showing better results. Younger patients performed better, but statistically insignificant. [37]

Yamazaki et al. 2015 found that patients with larger cochlear nerves performed better after cochlear implantation, highlighting the importance of cochlear nerve size in prelingually deaf children by comparing size of cochlear to that of fascial nerve. [39] In a study of twenty prelingually deaf children, **Morita et al. 2004** examined the relationship among cochlear implant outcome and cochlear nerve diameter on MRI. They found no correlation between the maximal diameter of the cochlear nerve and IT-MAIS scores or ECAP values. They came to the conclusion that, regardless of diameter, detecting the auditory nerve using MRI was adequate to anticipate better outcomes. [15]

After cochlear implantation, **Kim et al. 2013** investigated the connection between post-lingual patients' cochlear nerve size and hearing ability. They assessed the cochlear nerve diameter and CSA in 68 patients based on MR scans. They found that there was a negative correlation between the duration and degree of hearing loss and CSA. Additionally, they found a link between auditory performance and CSA. [18] We included prelingually deaf patients in our study. Interestingly, none of the patients in our group had hypoplastic or aplastic cochlear nerve (the cochlear nerves being larger than the facial nerves). The nerve thickness did not substantially correlate with postoperative audiologic performance, as predicted and supported by two prior studies. This could be the result of the nerve's irregular shape and inaccurate estimation of its actual size. We believe that while minor variations in the cochlear nerve's CSA appear normal, they may really reflect variations in the density of spiral ganglion cells, which could influence the results of cochlear implantation rather than the cochlear nerve's thickness.

Conclusion:

The variations of in the diameter of the cochlear nerve had non-significant difference on the outcome of CI as long as it is within the normal range.

Limitation of the study:

The relatively small number of children included in this study, there is a need for larger multi-center research in order to reliable assess the effect of cochlear nerve size on outcome of cochlear implant. Radiological assessment of cochlear nerve was done at one level.

Funding support: Our study did not receive any funding support.

Conflicts of interest: No

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