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Correlation of Electrophysiological and Behavioral Response in Cochlear Implant Candidates

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ABSTRACT

Objective: To determine the effect of Cochlear Implants on electrophysiological and behavioural response in children with hearing impairment at frequencies of 500, 1000, 2000, and 4000 Hz.

Study Design: Cross sectional study.

Place and Duration of Study: Department of ENT, Combined Military Hospital Rawalpindi Pakistan, from Jul 2021 to Jul 2022.

Methodology: Seventy children with hearing impairment aged 2-12 years of either gender, who had undergone cochlear implantation were part of the study. Language and hearing conditions were examined during the audiological assessment of candidates for cochlear implantation. At ER-tone 5A and TDH-39 using ISO 389-2 and 389-1 calibrations, warble tones given at different frequencies were used to derive behavioral air conduction thresholds. The Auditory Steady State Response test began with a carrier frequency of 500 Hz and advanced to frequencies of 1000, 2000, and 4000 Hz. Thresholds were set using a 10 dB down and 5 dB up procedure until no responses could be captured. Behavioral and Auditory Steady State Response responses were noted in all patients.

Results: Mean age of the patients was 6.66±2.74 years. Behavioral threshold>110 dB HL were obtained in 8(11.4%) subjects, 10(14.3%) had behavioral thresholds from 100 to 110 dB HL, and 52(74.3%) had <100 dB HL. Eleven patients obtained Auditory Steady State Response thresholds>110 dB HL (15.7%), 31(44%) achieved 100 to 110 dB HL and 28(40%) achieved <100 dB HL. The most common frequency was 500 Hz. Statistically insignificant difference was found between behavioral and Auditory Steady State Response thresholds (p=0.227).

Conclusion: Cochlear implantation has positive effect on behavioral and electrophysiological response in children with hearing impairment.

Keywords: Auditory Steady State Response, Cochlear Implant, Hearing Loss, Patient Outcome Assessment.

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INTRODUCTION

Cochlear Implant (CI) is a tested method for severe to profound bilateral hearing impairment to gain hearing again after implantation.[1] The age of patients with CI ranges from post-lingual adults with moderate hearing loss to child of six months with congenital severe hearing loss. Young children with numerous syndromic associations or disabilities are being implanted these days, therefore, even skilled audiologists may find it difficult to programme 'Difficult to MAP (Measurable Auditory Percept)' children using standard procedures.[1,2] Due to various problems such as cognitive difficulties, developmental delays and attention deficits, it may be difficult to obtain consistent responses from minors.[3] Due to age, listening experience, and cognitive ability disparities, it is probable that their behavior will be inconsistent in certain scenarios.[3,4] In such circumstances, an initial MAP can be programmed for them using objective electrophysiological measurements.

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This approach is very useful for creating a functional map for children, and it may be fine-tuned based on the child's habilitation performance and psychoacoustical input.[3] There have been instances where a child's behavioural Mapping levels were revealed inappropriate or erroneous, resulting in suboptimal habilitation outcomes. Troubleshooting and remapping may be necessary for children who have these issues.[5,6]

Auditory steady-state responses (ASSR) enable for intensities of up to 120 dB HL to be applied to frequency-specific stimulation.[7] The use of objective measurements to determine if a child's hearing is still intact before surgery can help determine if he or she has substantial hearing loss.[8] Despite reports of artifactual reactions to high-intensity ASSR by Gorga *et al*. and Small *et al*., the MASTER system addressed these problems.[9,10] However, only limited Pakistani data is available for ASSR to evaluate children with severe-to-profound hearing loss since 2004. As a result, in the current study, we examined the effect of CI on electrophysiological and behavioural response in children with hearing impairment at frequencies of 500, 1000, 2000, and 4000 Hz.

METHODOLOGY

The cross-sectional study was conducted at the ENT Department of Combined Military Hospital Rawalpindi Pakistan, from July 2021 to July 2022. The study was approved by the Institutional Ethical Review Committee (ERC approval no. 254/03/22). Sample sizes was estimated using PASS sample size calculator by considering statistics of behavioral responses ≤110 dB HL as 90%.[8] Non-probability convenience sampling was employed and informed consent was taken from all the patients.

Inclusion Criteria: Children with hearing impairment aged 2 to 12 years of either gender, who had cochlear implant were included.

Exclusion Criteria: Patients with enlarged vestibular aqueducts or cochlear nerve deficit, auditory neuropathy spectrum disease were excluded.

Baseline information regarding age at presentation, age at implantation and gender were obtained from all the participants. Hearing and language conditions were examined during the audiological assessment of candidates for CI. At ER-tone 5A (Etymotic Research) and TDH-39 using ISO 389-2 and 389-1 calibrations, warble tones given at 500, 1000, 2000, and 4000 Hz were used to derive behavioural air conduction thresholds. The highest limit of 120 dB HL for each frequency was used to obtain the threshold using a 10 dB down, 5 dB up approach. A good response was considered consistent if it occurred at least twice out of three times. Thresholds were determined using standard pure tone audiometry in children older than 1 year old. Only one individual had not been assessed after six months of wearing hearing aids.

The ASSR test began with a carrier frequency of 500 Hz and advanced to frequencies of 1000, 2000, and 4000 Hz. Using a 10 dB less and 5 dB more thresholds were set up for procedure until no responses could be captured. There were no false positives or false negatives or missing replies in any of the criteria. The thresholds of ASSR was set at lowest intensity at which a meaningful response could be observed, and a no response was discovered 5 dB below this level of intensity.

MASTER software was used to do the ASSR measurements on the Bio-Logic Navigator Pro System (version 2.04.i00). Continuous sinusoidal tones with 100% exponential amplitude and 20% frequency were employed to elicit air-conduction ASSR. ER-3A insert earphones were used to play these sinusoidal tones. Then, at 66.797 and 69.141Hz, 500, 1000, 2000, and 4000 Hz carrier frequencies were modulated in the left and right ears, respectively. Each stimulation cycle used a single frequency. For all frequencies, the greatest presentation level was 110 dB HL. Using an ANSI S3.6-1996-compliant sound level metre, we measured air-conduction stimuli in decibels of HL.

The maximum number of sweeps allowed by equipment was ten above 100 dB HL, twelve between 90 and 89 decibels, and eighteen between 80 and 89 decibels. Absent responses comprised behavioural and ASSR responses with thresholds ranging from 90 to 110 dB HL, as well as responses above 110 dB HL.

Statistical Package for Social Sciences (SPSS) version 23.0 was used for data analysis. The mean and standard deviation were used to describe numerical data, whereas frequencies and percentages were used to summarize categorical data. The Chi-square/Fisher exact test was used to compare behavioural reactions and ASSR with each frequency. The p-value of ≤0.05 was deemed statistically significant.

RESULTS

Of 71 patients, only one patient was excluded due to lost to follow-up. In our study, 37(52.9%) patients were males and 33(47.1%) were females. The mean age of the patients was 6.66±2.74 years with mean BMI 12.81±1.37 kg/m2. The mean age at CI implantation was 3.81±0.997 years. Unilateral CI was in 55(78.6%) cases and bilateral CI found in 15(21.4%) patients. Among 70 patients, 36(51.4%) patients had CI implant in their left ear and 34(48.6%) patients had CI in their right ear. (Table-I)

Behavioral threshold>110 dB HL were obtained in 8(11.4%) subjects, 10(14.3%) had behavioral thresholds from 100 to 110 dB HL, and 52(74.3%) were at levels lower than 100 dB HL. Eleven patients obtained ASSR thresholds>110 dB HL (15.7%), 31(44%) achieved 100 to 110 dB HL and 28(40%) achieved <100 dB HL. The most common frequency was 500 Hz. Descriptive analysis of thresholds is displayed in Table-II.

About 21 patients had behavioral and ASSR thresholds less than 100(40.4%), whereas 7 patients had behavioral and ASSR thresholds between 100-110(70%), and none of the patients behavioral and ASSR thresholds>110. Statistically insignificant difference was found between behavioral and ASSR thresholds (*p*=0.227). (Table-III)

Table-I: Baseline Demographics of Enrolled Children (n=71)

Variables	Mean±SD
Age (years)	6.66±2.74
Age Time at Cochlear Implants (years)	3.14±7.62
BMI (kg/m2)	12.81±1.37
	n(%)
Gender	
Male	37(52.9)
Female	33(47.1)
Type of Cochlear Implants	
Unilateral	55(78.6)
Bilateral	15(21.4)
Side of Cochlear Implants	
Left ear	36(51.4)
Right Ear	34(48.6)

Table-II: Comparison of Threshold among Cases (n=71)

Frequency (Hz)	n	Behavioral thresholds (Mean±SD)	ASSR thresholds (Mean±SD)	*p*-value
500	35	90.50±8.48	100.95±7.69	0.001
1000	10	94.15±11.57	95.69±9.78	0.749
2000	15	103.80±9.28	103.80±8.76	0.890
4000	10	92.12±3.35	102.78±7.26	0.002

Table-III: Comparison of Behavioral and ASSR Thresholds (n=71)

Behavioural thresholds	ASSR thresholds			*p*-value
	<100	100-110	>110	
<100	21(40.4%)	21(40.4%)	10(19.2%)	0.227
100-110	2(20%)	7(70%)	1(10%)	
>110	5(62.5%)	3(37.5%)	0	

DISCUSSION

To achieve the best possible programming results, the majority of post-lingual older children and adults with CIs exhibit sufficient behavioral reactions. Measurable Auditory Percepts (MAPs) need to be re-programmed on a regular basis based on behavioral reactions, even if these levels are accurate at the time of programming.[11,12] For children of very young age and those with syndromic associations/multiple impairments, establishing specific behavioral thresholds and comfort levels is exceedingly difficult. The observation method for behavior in implant programming on infants and toddlers is more likely to underestimate threshold values than methods that involve conditioned responses in older children.[13] Many studies have shown that CI is the best option for profound hearing loss, and that it improves oral language development and speech perception.[14-17] CI centers look for applicants who, while using hearing aids satisfactorily, are unable to profit from them. If the mean hearing thresholds in the free field with HAs demonstrate no access to speech sounds, the patients are considered candidates for CI.[18-20]

The limited reactions to high-intensity ASSRs was the most notable result in this investigation. Due to a lack of prior understanding regarding behavioural thresholds, we were only able to record at 110 dB HL at the highest frequencies. We selected lower sound volume levels for safety concerns. Prior to the ASSR test, the only audiological data available was missing click ABR at 90 dB HL (high level). A child's degree of severe or profound hearing loss has nothing to do with whether or not auditory circuits in premature babies are still developing.[21] We were also concerned about artifactual reactions that exceeded the previously set 110 dB HL threshold. In patients with hearing loss, there is a strong correlation between ASSR and behavioral tests. The narrower the gap between ASSR and tonal thresholds, the higher the degree of hearing loss.[22,23]

Adults' 80-Hz ASSR response amplitudes were found to be 5 times lower than 40-Hz response amplitudes in previous studies. According to Tlumak *et al*., children's 80 Hz-ASSR amplitudes were lower than their 40 Hz repetition rates.[24] In certain cases, 10 sweeps are insufficient to reduce noise to below 30 nV; in these cases, we propose recording for an additional 12 sweeps. Muhler *et al*. suggest a stimulation rate of 40 Hz as an option. There is no indication that narrow band chirps can be employed in high-intensity ASSR stimulation.[25]

LIMITATION OF STUDY

Some answers may have been missed due to a low signal-to-noise ratio, which is common for ASSR amplitudes at threshold levels. In general, as the EEG amplitude and recording time increase, so does the noise level. No more than ten sweeps are collected for any stimulus intensity that exceeds 100 dB HL. Because of the small amplitudes around the threshold and possibly increasing noise levels, utilising just 10 sweeps may make capturing responses with a high signal-to-noise ratio challenging (1 sweep contains 16 epochs of 1.024 s, so the recording time was 163 s for each frequency, less than 3 min). Longer recording periods with Chirp stimuli may result in larger response amplitudes and a higher signal-to-noise ratio. Among 70 paediatric CI candidates, the lack of high-intensity ASSR responses (specificity >90%) predicted behavioural thresholds in the severe hearing loss range. These findings lend credence to CI. These findings are advantageous.

CONCLUSION

Cochlear implantation has positive effect on behavioral and electrophysiological response in children with hearing impairment.

Conflict of Interest: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SBHS & ZS: Conception, study design, drafting the manuscript, approval of the final version to be published.

MA & MZK: Data acquisition, data analysis, drafting the manuscript, critical review, approval of the final version to be published.

MR & WUDS: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Deep NL, Dowling EM, Jethanamest D, Carlson ML. Cochlear Implantation: An Overview. J Neurol Surg B Skull Base 2019; 80(2): 169-177. https://doi.org/10.1055/s-0038-1669411
2. Jallu AS, Hussain T, Hamid WU, Pampori RA. Prelingual Deafness: An Overview of Treatment Outcome. Indian J Otolaryngol Head Neck Surg 2019; 71(Suppl 2): 1078-1089. https://doi.org/10.1007/s12070-017-1181-7
3. Nandhan R, Ravikumar A, Kameswaran M, Mandke K, Ranjith R. A clinical study of electrophysiological correlates of behavioural comfort levels in cochlear implantees. Cochlear Implants Int 2014; 15. https://doi.org/10.1179/1754762814Y.0000000064
4. Charroó LE, Bermejo S, Paz Cordovez AS, Rodríguez C, Finley CC, Saoji AA. Effect of Number of Electrodes Used to Elicit Electrical Stapedius Reflex Thresholds in Cochlear Implants. Audiol Neurootol 2021; 26(3): 164-172. https://doi.org/10.1159/000510467
5. Vaerenberg B, De Ceulaer G, Szlávik Z, Mancini P, Buechner A, Govaerts PJ. Setting and reaching targets with computer-assisted cochlear implant fitting. Sci World 2014; 2014: 646590. https://doi.org/10.1155/2014/646590
6. Rasmussen KMB, West NC, Bille M, Sandvej MG, Cayé-Thomasen P. Cochlear Implantation Improves Both Speech Perception and Patient-Reported Outcomes: A Prospective Follow-Up Study of Treatment Benefits among Adult Cochlear Implant Recipients. J Clin Med 2022; 11(8). https://doi.org/10.3390/jcm11082257
7. Frosolini A, Badin G, Sorrentino F, Brotto D, Pessot N, Fantin F, et al. Application of Patient Reported Outcome Measures in Cochlear Implant Patients: Implications for the Design of Specific Rehabilitation Programs. Sensors 2022; 22(22): 8770. https://doi.org/10.3390/s22228770
8. Beck RM, Grasel SS, Ramos HF, Almeida ER, Tsuji RK, Bento RF, et al. Are auditory steady-state responses a good tool prior to pediatric cochlear implantation? Int J Pediatr Otorhinolaryngol 2015; 79(8): 1257-1262. https:doi.org/10.1016/j.ijporl.2015.05.026
9. Gorga MP, Neely ST, Hoover BM, Dierking DM, Beauchaine KL, Manning C. Determining the upper limits of stimulation for auditory steady-state response measurements. Ear Hear 2004; 25(3): 302-307. https://doi.org/10.1097/01.aud.0000130801.96611.6b
10. Small SA, Stapells DR. Artifactual responses when recording auditory steady-state responses. Ear Hear 2004; 25(6): 611-623. https://doi.org/10.1097/00003446-200412000-00009
11. Brown CJ, Hughes ML, Luk B, Abbas PJ, Wolaver A, Gervais J. The relationship between EAP and EABR thresholds and levels used to program the nucleus 24 speech processor: data from adults. Ear Hear 2000; 21(2): 151-163. https://doi.org/10.1097/00003446-200004000-00009
12. Kalkman RK, Briaire JJ, Dekker DMT, Frijns JHM. The relation between polarity sensitivity and neural degeneration in a computational model of cochlear implant stimulation. Hear Res 2022; 415: 108413. https://doi.org/10.1016/j.heares.2021.108413
13. Brown CJ. Clinical uses of electrically evoked auditory nerve and brainstem responses. Curr Opin Otolaryngol Head Neck Surg 2003; 11(5): 383-387. https://doi.org/10.1097/00020840-200310000-00013
14. Entwisle LK, Warren SE, Messersmith JJ. Cochlear Implantation for Children and Adults with Severe-to-Profound Hearing Loss. Semin Hear 2018; 39(4): 390-404. https://doi.org/10.1055/s-0038-1670705
15. Souza P, Hoover E. The Physiologic and Psychophysical Consequences of Severe-to-Profound Hearing Loss. Semin Hear 2018; 39(4): 349-363. https://doi.org/10.1055/s-0038-1670698
16. Turunen-Taheri S, Carlsson PI, Johnson AC, Hellström S. Severe-to-profound hearing impairment: demographic data, gender differences and benefits of audiological rehabilitation. Disabil Rehabil 2019; 41(23): 2766-2774. https://doi.org/10.1080/09638288.2018.1477208
17. D'Haese PSC, van Rompaey V, De Bodt M, Van de Heyning P. Severe Hearing Loss in the Aging Population Poses a Global Public Health Challenge. How Can We Better Realize the Benefits of Cochlear Implantation to Mitigate This Crisis? Front Public Health 2019; 7: 227. https://doi.org/10.3389/fpubh.2019.00227
18. Hoppe U, Hesse G. Hearing aids: indications, technology, adaptation, and quality control. GMS Curr Top Otorhinolaryngol Head Neck Surg 2017; 16. https://doi.org/10.3205/cto000147
19. Holt RF. Assistive Hearing Technology for Deaf and Hard-of-Hearing Spoken Language Learners. Educ Sci 2019; 9(2). https://doi.org/10.3390/educsci9020153
20. Langner F, Arenberg JG, Büchner A, Nogueira W. Assessing the relationship between neural health measures and speech performance with simultaneous electric stimulation in cochlear implant listeners. PLoS One 2021; 16(12): e0261295. https://doi.org/10.1371/journal.pone.0261295
21. Vlastarakos PV, Vasileiou A, Nikolopoulos TP. The value of ASSR threshold-based bilateral hearing aid fitting in children with difficult or unreliable behavioral audiometry. Ear Nose Throat J 2017; 96(12): 464-468. https://doi.org/10.1177/014556131709601207

22. Macherey O, Carlyon RP, Chatron J, Roman S. Effect of Pulse Polarity on Thresholds and on Non-monotonic Loudness Growth in Cochlear Implant Users. J Assoc Res Otolaryngol 2017; 18(3): 513-527. https://doi.org/10.1007/s10162-016-0614-4
23. Mesnildrey Q, Venail F, Carlyon RP, Macherey O. Polarity Sensitivity as a Potential Correlate of Neural Degeneration in Cochlear Implant Users. J Assoc Res Otolaryngol 2020; 21(1): 89-104. https://doi.org/10.1007/s10162-020-00742-7
24. Tlumak AI, Durrant JD, Delgado RE, Boston JR. Steady-state analysis of auditory evoked potentials over a wide range of stimulus repetition rates: profile in children vs. adults. Int J Audiol 2012; 51(6): 480-490. https://doi.org/10.3109/14992027.2012.664289
25. Mühler R, Rahne T, Mentzel K, Verhey JL. 40-Hz multiple auditory steady-state responses to narrow-band chirps in sedated and anaesthetized infants. Int J Pediatr Otorhinolaryngol 2014; 78(5): 762-768. https://doi.org/10.1016/j.ijporl.2014.02.005

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