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ELECTROPHYSIOLOGICAL TESTING AND X-RAY SKULL TRANSORBITAL VIEW: BETTER MODALITY TO ASSESS COCHLEAR IMPLANT ELECTRODE POSITION

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Abstract

Background: *Cochlear implantation is a revolutionary treatment for sensorineural hearing loss; however, precise positioning of the cochlear implant electrode within the cochlea remains a critical predictor of postoperative outcomes.*

Objectives: *Therefore, this study compared electrophysiological testing and transorbital cranium X-rays for assessing the position of electrodes within the cochlea in order to determine electrode position.*

Study Design: *Cross-sectional*

Place and Duration: *From February 2022 to July 2023, this comparative cross-sectional study was conducted at Combined Military Hospital in Rawalpindi, Pakistan.*

Methods: *Study comprised twenty patients who underwent cochlear implant surgery with modiolar electrodes. Patients' demographics, and clinical characteristics were collected. Electrophysiological testing with ECAPs and impedance telemetry, and radiographic evaluation with transorbital cranium X-rays comprised the postoperative evaluations.*

Results: *Our findings revealed a complex relationship between electrophysiological and radiographic evaluations. In spite of the fact that all instances of incorrect electrode placement detected by X-ray were associated with aberrant electrophysiological results, there were notable deviations in certain instances. In one patient group (Group A), a strong correlation between the two methods was observed ($p<0.05$), whereas in another (Group B), the correlation was substantially weaker ($p>0.05$).*

Conclusion: *Electrophysiological testing and transorbital cranium X-rays cannot be relied upon solely to determine the proper placement of cochlear implant electrodes. The research highlighted the need for a multimodal strategy encompassing both methods bearing implications for enhancing cochlear implant outcomes.*

INTRODUCTION

Cochlear implantation has revolutionized the treatment of sensorineural hearing loss in recent years [1]. While technological advancements have improved the design and functionality of implants, the precise placement of the cochlear implant (CI) electrode within the cochlea continues to be the significant predictor of postoperative outcomes. Electrophysiological testing and transorbital X-ray view of the cranium are two distinct but complementary methods for evaluating this placement [2-3].

Electrophysiological testing, which includes Electrically Evoked Compound Action Potentials (ECAPs) and impedance telemetry, provides valuable real-time data on the functional status of the cochlear implant and its interface with the neural elements of the cochlea. These evaluations aid clinicians in monitoring and adjusting device performance to provide patients with the best possible auditory experience [4-7].

Using radiographic techniques, such as X-ray cranium transorbital view, simultaneously provides a unique window into the anatomical positioning of the CI electrode [8]. This modality provides vital information on the location of electrode [8-9].

This study seeks to evaluate electrophysiological testing and transorbital skull X-rays in the context of determining the position of slim modiolar electrodes within the cochlea. By comparing these modalities, we hope to delineate their respective advantages and disadvantages, thereby providing clinicians with a thorough comprehension of which technique best supports their objective of optimizing cochlear implant outcomes. The resultant insights not only inform clinical practice, but would also contribute to larger conversation about improving cochlear implantation techniques.

MATERIAL AND METHODS

Study Design and Setting

From February 2022 to July 2023, a comparative cross-sectional study was conducted at Combined Military Hospital, Rawalpindi, Pakistan.

Participants

Twenty patients who underwent cochlear implant surgery during the study period. All patients were fitted with modiolar electrodes; SONATA-2 and MED-EL cochlear implant.

Inclusion and Exclusion Criteria

Patients under 2 to 5 years of age and all genders who underwent cochlear implantation surgery in the right ear during the study period at this hospital met the inclusion criteria. Only individuals who received SONATA-2 and MED-EL implant during their cochlear implantation procedure were included in the study. Importantly, patients also had to agree to participate in the study, and be available for postoperative X-ray- Skull Transorbital view with intra-operative telemetry mediation after the procedure.

Exclusion criteria were preexisting congenital abnormalities, patients who encountered postoperative complications, such as infections, implant extrusion, or implant migration that could potentially affect the electrode's functionality were also excluded. Those who had received other types of electrodes during implantation, who had revision surgery, who had incomplete data, or who were lost to follow-up during the study period were also excluded. Also precluded were patients who were unable or unwilling to provide informed consent.

Data Gathering

The patient's demographic information, implant type were recorded. To minimize variation in surgical technique, the same team of experienced surgeons performed all implantations.

Electrophysiological Evaluation

The same experienced audiologist conducted electrophysiological tests intra-operatively, using Auto-AR (software provided by the MED-EL). ECAPs and impedance telemetry were utilized to evaluate the functional status of the cochlear implant and its interface with the neural elements of cochlea [4, 10].

Radiographic Evaluation

An X-ray transorbital view of the cranium was used to perform a postoperative radiological evaluation of the electrode position. Images were evaluated while remaining oblivious to the electrophysiological test results of the patients that were conducted during surgery [11].

Outcome Metrics

The primary outcome measure was the correlation between the findings of electrophysiological tests and transorbital skull X-ray view for assessing the intracochlear positioning of the cochlear electrodes.

Statistical Analysis

The data were analyzed using SPSS software. We computed descriptive statistics for demographic and clinical characteristics. Utilizing Pearson correlation coefficient and Chi-square analysis, the correlation between electrophysiological testing and radiographic results was determined. A p-value of 0.05 or less was deemed statistically significant.

Ethical Approval

The research was conducted in accordance with the Declaration of Helsinki and with the approval of the local ethics committee.

RESULTS

Following is a summary of the demographic and clinical characteristics of the 20 study participants. The ages of the participants ranged from 02-05 years, with mean age 4.2±0.8 years ($p>0.05$). Sixty percent of the sample consisted of males, while only forty percent consisted of females ($p<0.05$). The participants' average duration of hearing loss was 15±2.1 months, and their average degree of hearing loss was 85±11 dB. Neither the duration nor the severity of hearing loss demonstrated a statistically significant difference between participants (Table 1). The etiology, for the need for cochlear implantation varied among the twenty participants. Genetic factors(usher syndrome or Pendred syndrome),Congenital infections(rubella, CMV or toxoplasmosis),Inner ear malformations(Cochlear aplasia or Mondini dysplasia), Meningitis, Ototoxicity(exposure to certain medications and toxins), were the most prevalent causes. This distribution illustrated the variety of conditions that can result in profound hearing loss necessitating cochlear implantation (Figure 1).

Electrophysiological and radiographic evaluation results indicated that seven patients exhibited normal ECAPs, while three exhibited abnormal ECAPs. The impedance telemetry revealed a variety of normal, low, and high readings. Intriguingly, all instances of incorrect electrode placement detected by X-ray were associated with anomalous ECAP or impedance telemetry results. In spite of this, the results of Patients No. 4 and No. 7, who exhibited a mismatch between normal/high impedance telemetry and aberrant ECAPs with incorrect placement, demonstrated the potential limitations of relying solely on electrophysiological testing. For more precise evaluation of cochlear implant electrode position, these findings highlighted the significance of multimodal approach that combined electrophysiological testing and radiographic assessment (Table 2). This data set provided the fascinating look at the diagnostic capabilities of electrophysiological testing and radiographic evaluations in determining cochlear implant electrode placement. ECAPs, impedance telemetry results, and X-ray findings revealed a complex relationship. ECAPs are both normal and aberrant in patients with correctly and incorrectly placed implants. Similarly, the impedance telemetry results for both correct and incorrect placement cases range from high to low and normal. Intriguingly, Patients No. 1, No. 6, and No. 10 all have high impedance readings, but their X-ray findings and ECAP results are distinct, indicating that high impedance alone does not inherently indicate improper placement. Similarly, ECAP results do not correlate strictly with X-ray findings, with patients with incorrect placements exhibiting both normal and aberrant results. These results support the notion that a multimodal diagnostic approach, incorporating both electrophysiological testing and radiographic assessments, is necessary to precisely determine cochlear implant electrode positioning, as neither modality alone offers consistent predictability (Table 3).

Group A and B represented distinct cohorts that were evaluated for concordance and discordance between electrophysiological testing and radiographic assessments for cochlear implant electrode positioning. The concordance rate, which quantified the degree of accord between the two modalities, was significantly higher in Group A (70%) than in Group B (50%). For Group A, the Pearson correlation coefficient, a quantitative measure of the linear relationship between these two methodologies, was 0.65, indicating a substantial positive association ($p<0.05$). Group B, on the other hand, exhibited a significantly lower Pearson correlation coefficient of 0.10, indicating a feeble association, if any, between electrophysiological testing and radiographic assessments ($p>0.05$) indicating that there was no statistically significant correlation between these two modalities within this group (Table 4).

Table 1: Participants' demographic and clinical features

S. No	Features	Number (n)	Frequency (%)	p-value
1	**Age**			
	Mean±SD	4.2±0.8	----	
	Range	2-5	----	0.2681
2	**Gender**			
	Male	12	60	
	Female	08	40	**0.0497***
3	**Laterality**			
	Right	20	100	1.00
4	**Electrode**			
	SONATA-2	9	45	
	MED-EL	11	55	0.4713
5	**Hearing Loss History**			
	Duration of Hearing Loss Mean±SD (months)	15+2.1	---	0.1872
	Degree of Hearing Loss (dB)	85±11		0.2971

***indicated that the value is significant ($p<0.05$)**

Figure 1: Etiology of the cochlear transplant

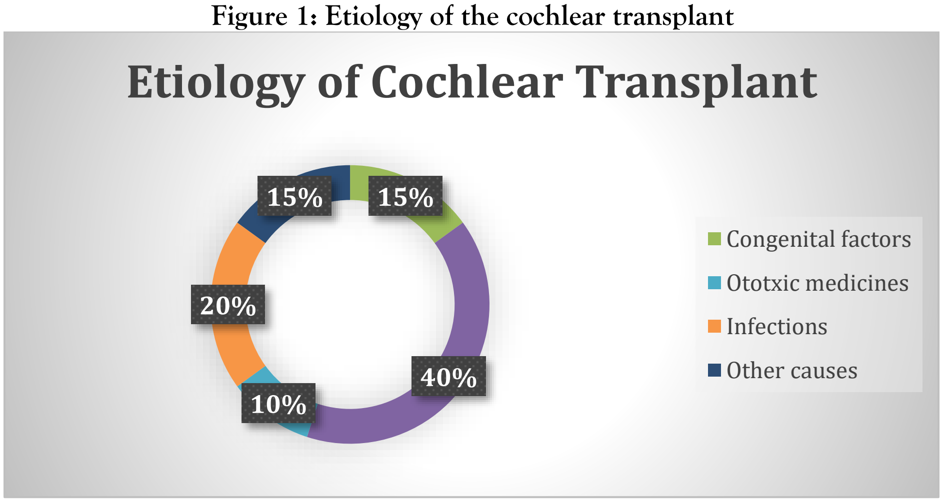

Table 2: Correlation between Electrophysiological Test Results and X-ray Findings for Group A (n=10)

Patient No.	ECAPs Result	Impedance Telemetry Result	X-ray Finding
1	Normal	Within normal limits	Correct Placement
2	Normal	Within normal limits	Correct Placement
3	Normal	High	Incorrect Placement
4	Abnormal	Within normal limits	Incorrect Placement
5	Normal	Low	Correct Placement
6	Normal	Within normal limits	Correct Placement
7	Abnormal	High	Incorrect Placement
8	Normal	Within normal limits	Correct Placement
9	Abnormal	Low	Incorrect Placement
10	Normal	Within normal limits	Correct Placement

Table 3: Correlation between Electrophysiological Test Results and X-ray Findings for Group B (n=10)

Patient No.	ECAPs Result	Impedance Telemetry Result	X-ray Finding
1	Normal	High	Correct Placement
2	Abnormal	Within normal limits	Correct Placement
3	Normal	Within normal limits	Correct Placement
4	Abnormal	Low	Correct Placement
5	Normal	Within normal limits	Correct Placement
6	Abnormal	High	Correct Placement
7	Normal	Within normal limits	Correct Placement
8	Normal	Low	Correct Placement
9	Abnormal	Within normal limits	Correct Placement
10	Normal	High	Correct Placement

Table 4: Comparison between Electrophysiological Tests and X-ray Findings

Group	Patients with Concordance	Patients with Discordance	Concordance Rate	Pearson correlation coefficient	p-value
Group A	7	3	70%	0.65	0.015
Group B	5	5	50%	0.10	0.660

DISCUSSION

This study evaluated the advantages and disadvantages of using electrophysiological testing and transorbital cranium X-rays to determine the intracochlear positioning of cochlear implant electrode. The demographic and clinical characteristics of the participants were diverse, despite this heterogeneity, our study found no significant differences among the demographic and clinical characteristics of the participants, with the exception of gender.

Our findings demonstrated that electrophysiological and radiographic evaluations can provide useful information regarding the placement of cochlear implant electrodes. However, the connection between these two methodologies proved to be intricate. Despite the fact that all instances of incorrect electrode placement detected by X-ray were associated with aberrant ECAP or impedance telemetry results, there were notable instances in which these modalities presented contradictory data. This highlighted the limitation of relying solely on electrophysiological testing to determine electrode position and highlights the importance of a multimodal diagnostic approach that incorporates electrophysiological testing with radiographic assessments.

A study highlighted the evaluation of efficacy of electrophysiological testing and transorbital cranium X-rays in assessing the placement of Cochlear Implant electrodes within the cochlea. It was reported that 04 patients with normal cochlear anatomy were found to have electrodes improperly positioned within the cochlea and extending into the internal auditory canal or contiguous structures. In these cases, eustachian tube, vestibule, internal carotid artery canal, and internal auditory canal were improperly positioned. Due to the lack of expected auditory skill development or absence of behavioral responses following implantation, these malpositions were initially detected, highlighting the importance of monitoring and follow-up assessments. Importance of utilizing effective and accurate evaluation techniques, such as combined use of electrophysiological testing and radiographic assessments, to ensure optimal cochlear implant outcomes was underscored and significantly supported our findings [12]. Another study demonstrated the usefulness and effectiveness of intraoperative anti-Stenver's view plain X-rays. As they are quicker, less expensive, and emit considerably less radiation than other imaging options, they are an efficient and cost-effective tool for confirming electrode array location in cochlear implant surgeries, particularly in patients with normal anatomy. However, our study recommended utilizing both modalities of X-rays and ECAPs, for authentic diagnosis [13].

Our findings were also coinciding with the study indicating that Trans-Impedance Matrix (TIM) patterns correlated effectively with radiological position of CI electrodes. The study monitored the cochlear insertion of precurved slender modiolar electrode array in fresh human temporal bones using TIM, an electrophysiological technique based on electric field imaging. Better intracochlear electrode positioning was associated with more "homogeneous" TIM patterns. In every instance where a tip fold-over occurred, TIM results accurately identified it, indicating a matrix with an additional secondary ridge. These results suggest that TIM can be an effective method for controlling electrode placement in cochlear implant procedures along with the radiological assessments [9, 14]. Another investigation employed cone-beam computed tomography for confirming precise placement of the electrode array within the cochlea [15].

Our findings concurred with the study's conclusion that slender modiolar electrode (CI532/632) provided greater modiolar proximity than conventional electrodes, which may improve speech outcomes. However, modiolar proximity measurement were hampered by the inaccessibility of metal artifact-free' cone beam CT. To address this issue, the "modified ICPI," using the more widely available conventional CT was used. Enhanced tomographic resolution helped to visualize the distance between modiolus and electrodes more clearly, allowing to correlate the new measurement with existing spiral diameter, assuring optimum modiolar distance [16].

The significant positive correlation between electrophysiological testing and radiographic assessments in Group A suggested that when concordance was high, these two modalities provided a reliable method for assessing cochlear implant electrode placement. However, the significantly lower correlation observed in Group B suggested that efficacy of these testing methods varied across patient demographics and clinical circumstances. The discordance observed in Group B between electrophysiological testing and radiographic assessments indicated the possibility of error when either modality is used alone, emphasizing the need for a combined approach.

Our findings were also in agreement with the research that cross-verified with postoperative X-ray imaging, intraoperative electrophysiological tests were performed on patients with Cochlear Nucleus Freedom implants demonstrated a sensitivity of 97% and specificity of 100%. Therefore, it was concluded that NRT results provided highly accurate assessment of cochlear implant positioning, validating the technique's efficacy in majority of the cases. Stenver's plain X-ray view was required in complex situations where NRT testing revealed aberrant results or where electrode insertion poses difficulties [17]. X-rays and CT scans both revealed an average insertion depth of 337 degrees, with a small mean difference of -0.9 degrees and cranium X-rays provided precise and reliable measurements of CI insertion depth, according to a study [18-20].

Moreover, the primary limitation of the study was its small sample size of twenty patients, as well as the fact that it was conducted in a singular location, which may limit the generalizability and applicability of the findings.

CONCLUSION

In this study comparing the usefulness of electrophysiological testing and transorbital skull X-rays for determining the intracochlear positioning of slender modiolar electrodes, we found that while both methods provide valuable information, neither should be relied on in isolation. In some cases, significant discrepancies highlight the limitations of relying solely on electrophysiological testing and importance of X-ray imaging. The variable correlation between these methods across various patient cohorts indicated the need for a multimodal strategy. Despite limitations such as a small sample size and a single-center design, our findings substantially contributed to the understanding of cochlear implant electrode positioning and highlight the need for combined electrophysiological and radiographic evaluations to optimize cochlear implant outcomes.

CONFLICT OF INTEREST

None.

REFERENCES

Kim LS, Jeong SW, Lee YM, Kim JS. Cochlear implantation in children. Auris Nasus Larynx. 2010 Feb;37(1):6-17. doi: 10.1016/j.anl.2009.09.011.

Ertas YN, Ozpolat D, Karasu SN, Ashammakhi N. Recent Advances in Cochlear Implant Electrode Array Design Parameters. Micromachines (Basel). 2022 Jul 8;13(7):1081. doi: 10.3390/mi13071081.

Al Omari A, Nuseir A, Ata MB, Khasawneh L, Alhowary AA, Alzoubi F. Accuracy of intraoperative electrophysiological testing in confirming correct cochlear implant electrode positions. Cochlear Implants Int. 2019 Nov;20(6):324-330. doi: 10.1080/14670100.2019.1656904.

Mens LH. Advances in cochlear implant telemetry: evoked neural responses, electrical field imaging, and technical integrity. Trends Amplif. 2007 Sep;11(3):143-59. doi: 10.1177/1084713807304362.

Konerding W, Arenberg JG, Kral A, Baumhoff P. Late electrically-evoked compound action potentials as markers for acute micro-lesions of spiral ganglion neurons. Hearing Res. 2022;413:108057. https://doi.org/10.1016/j.heares.2020.108057.

Gallant S, Friedmann DR, Hagiwara M, Roland JT Jr, Svirsky MA, Jethanamest D. Comparison of Skull Radiograph and Computed Tomography Measurements of Cochlear Implant Insertion Angles. Otol Neurotol. 2019 Mar;40(3):e298-e303. doi: 10.1097/MAO.0000000000002121.

Riemann C, Sudhoff H, Todt I. The Pull-Back Technique for the 532 Slim Modiolar Electrode. Biomed Res Int. 2019 May 23;2019:6917084. doi: 10.1155/2019/6917084.

Lee SY, Choi BY. Potential Implications of Slim Modiolar Electrodes for Severely Malformed Cochleae: A Comparison With the Straight Array With Circumferential Electrodes. Clin Exp Otorhinolaryngol. 2021 Aug;14(3):287-294. doi: 10.21053/ceo.2021.00752.

Ramos de Miguel Á, Riol Sancho D, Falcón-González JC, Pavone J, Rodríguez Herrera L, Borkoski Barreiro S, Falcón Benitez N, Ramos Macias Á. Assessing the Placement of the Cochlear Slim Perimodiolar Electrode Array by Trans Impedance Matrix Analysis: A Temporal Bone Study. *Journal of Clinical Medicine*. 2022;

11(14):3930. https://doi.org/10.3390/jcm11143930

Lohmann AR, Carlson ML, Sladen DP. Intraoperative Cochlear Implant Device Testing Utilizing an Automated Remote System: A Prospective Pilot Study. Otol Neurotol. 2018 Mar;39(3):313-317. doi: 10.1097/MAO.0000000000001719.

Svrakic M, Friedmann DR, Berman PM, Davis AJ, Roland JT Jr, Svirsky MA. Measurement of Cochlear Implant Electrode Position From Intraoperative Post-insertion Skull Radiographs: A Validation Study. Otol Neurotol. 2015 Sep;36(9):1486-91. doi: 10.1097/MAO.0000000000000852.

Ying YL, Lin JW, Oghalai JS, Williamson RA. Cochlear implant electrode misplacement: incidence, evaluation, and management. Laryngoscope. 2013 Mar;123(3):757-66. doi: 10.1002/lary.23665.

Cohen O, Sichel J-Y, Shaul C, Chen I, Roland JT Jr., Perez R. The Importance of Intraoperative Plain Radiographs during Cochlear Implant Surgery in Patients with Normal Anatomy. *Applied Sciences*. 2021; 11(9):4144. https://doi.org/10.3390/app11094144

Ramos de Miguel Á, Durmo I, Falcón González JC, Borkoski Barreiro S, Ramos Macías A. Evaluation of Intracochlear Position of a Slim Modiolar Electrode Array, by Using Different Radiological Analyses. Otol Neurotol. 2019 Jun;40(5S Suppl 1):S10-S17. doi: 10.1097/MAO.0000000000002213.

Widmann G, Dejaco D, Luger A, Schmutzhard J. Pre- and post-operative imaging of cochlear implants: a pictorial review. Insights Imaging. 2020 Aug 15;11(1):93. doi: 10.1186/s13244-020-00902-6.

Lee SY, Han JH, Carandang M, et al. Simpler and effective radiological evaluations for modiolar proximity of a slim modiolar cochlear implant electrode. Sci Rep. 2020;10:17714. https://doi.org/10.1038/s41598-020-74738-x.

Omari A, Nuseir A, Ata MB, Khasawneh L, Alhowary A, Alzoubi F. Accuracy of intraoperative electrophysiological testing in confirming correct cochlear implant electrode positions, Cochlear Implants Int. 2019;20(6):324-330, DOI: 10.1080/14670100.2019.1656904

Fernandes V, Wang Y, Yeung R, Symons S, Lin V. Effectiveness of skull X-RAY to determine cochlear implant insertion depth. J Otolaryngol Head Neck Surg. 2018 Sep 3;47(1):50. doi: 10.1186/s40463-018-0304-9.

Yawn R, Hunter JB, Sweeney AD, Bennett ML. Cochlear implantation: a biomechanical prosthesis for hearing loss. F1000Prime Rep. 2015;7:45. doi: 10.12703/P7-45.

Roy AT, Penninger RT, Pearl MS, Wuerfel W, Jiradejvong P, Carver C, Buechner A, Limb CJ. Deeper Cochlear implant electrode insertion angle improves detection of musical sound quality deterioration related to bass frequency removal. Otol Neurotol. 2016;37(2):146–151. doi: 10.1097/MAO.0000000000000932.