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COCHLEAR IMPLANT OUTCOMES IN ADULTS: FACTORS INFLUENCING SPEECH RECOGNITION SUCCESS

Dr Mohan Bhatnagar[1], Dr. Nitin Chauhan[2], Dr Rajeev Kumar Gupta[*3]

1Assistant Professor Department of OTO-RHINOLARYNGOLOGY K. D. Medical College, Hospital & Research Center, Mathura (UP)
2Associate Professor Department of General Medicine K. D. Medical College, Hospital & Research Center, Mathura (UP)
3Associate Professor Department of OTO-RHINOLARYNGOLOGY
K. D. Medical College, Hospital & Research Center, Mathura (UP)

Corresponding Author: Dr Rajeev Kumar Gupta
Associate Professor Department of OTO-RHINOLARYNGOLOGY K. D. Medical College, Hospital & Research Center, Mathura (UP)

Abstract

Adults with severe-to-profound hearing loss get better results from cochlear implants, but results between different people vary greatly. Our study identifies why CI operations succeed by looking at what happens before surgery, when patients get their implants, and after surgery when they receive treatment. Our review of 150 adults' data showed their ability to understand speech better when they had been deaf for only a short time, got their implant at a young age, and had good thinking skills. Regular sessions with rehab improved recovery results more than any other factor. People who got the implant at an older age performed just as well over time as younger recipients if they worked hard during their rehabilitation exercises. The study outcomes show how healthcare leaders must create custom patient choices, complete before-implant tests, and organize specific recovery exercises. Three new ways forward are using machine learning to predict results, creating virtual rehab tools, and designing mental ability tests specifically for people with hearing problems. This research develops a method to improve Cochlear Implant results while better taking care of patients.

Keywords: *cochlear implants, speech recognition, hearing loss, rehabilitation, cognitive function, duration of deafness, age at implantation.*

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1.0 Introduction

Cochlear implants (Cis) have been revolutionizes the treatment of the severe to profound sensorineural loss of the hearing in the adults. However the post implementation of the speech recognition outcomes may vary significantly among the recipients. The factors that influencer these outcomes is crucial for the optimization of the selection of the patient and the strategies of rehabilitation. This study investigates the key predictors of the success of CI and focusing on the pre-operative characteristics age at the implementation and the protocols of post implants of rehabilitation. Through analyzing the factors it is aimed to develop the comprehensive framework for the predicting and improvement of the speech recognition outcomes in the adult CI recipients.

2.0 Literature review

2.1 Impact of Duration of Deafness & Age

The age at the implantation and the duration of the deafness are consistently identified as critical factors influencing the recognition of the speech outcomes in the adults with Cochlear Implants.

According to Bayea, 2016 and Budenz, 2011 they highlighted that older recipients generally achieve poorer outcomes when it is compared to younger recipients. It happens largely due to age related declines in neural plasticity and auditory process of the capabilities.

According to Lazard, 2012 the duration of deafness before the implementation also negatively impact performance as prolonged auditory lack can reduce the ability of brain’s to adapt to new auditory inputs.

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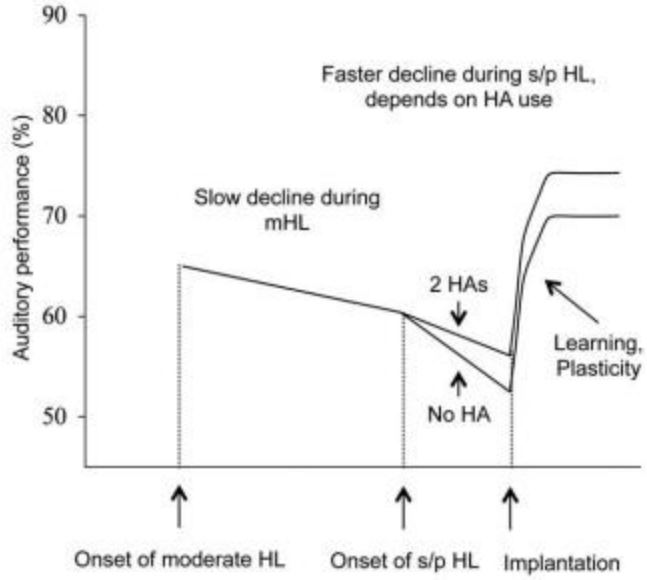

Figure 1: Three-stage model of mean expected auditory performance ranking over time for a hypothetical ‘‘average CI recipient

(Source: Lazard et al., 2012)

As per the Garcia Iza, 2048 many elderly patients still achieve long term improvement indicating the other factors like technical advancement and cognitive way which can mitigate the effects of age and deaf duration.

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Participant	Gender	Age (years)	Implantation age (years)	SES	Side of implant	Hearing aid	Etiology of hearing loss	Better ear PTA (dB HL)	Sentence recognition (% correct words)
1	Female	64	54	24	Both	No	Genetic	120.0	96.0
2	Female	66	62	35	Right	Yes	Genetic, progressive as adult	78.8	59.2
3	Male	66	61	18	Left	No	Noise, Meniere's disease	82.5	66.4
4	Female	66	58	12	Right	Yes	Genetic, progressive as adult	98.8	92.0
6	Male	69	65	24	Right	No	Genetic, progressive as adult	88.8	76.0
7	Male	58	52	36	Both	No	Rubella, progressive	115.0	25.6
8	Female	56	48	25	Right	Yes	Genetic, progressive	82.5	84.0
9	Male	79	67	49	Left	No	Genetic	120.0	0.0
10	Male	79	76	36	Right	Yes	Progressive as adult, noise, sudden	70.0	73.6
12	Female	68	56	12	Both	No	Otosclerosis, progressive as adult	112.5	25.6
13	Male	54	50	24	Both	No	Progressive as adult	120.0	84.8
16	Female	62	59	35	Right	No	Progressive as adult	115.0	17.6
19	Female	75	67	36	Left	No	Progressive as adult, autoimmune	120.0	1.6
20	Male	78	74	15	Left	No	Ear infections	108.8	0.0
21	Male	82	58	42	Left	Yes	Meniere's disease	71.3	55.2
23	Female	80	73	30	Right	No	Progressive as adult	87.5	35.2
25	Male	58	57	24	Right	Yes	Autoimmune, sudden	120.0	3.2
28	Male	77	72	12	Both	No	Progressive as adult	120.0	0.8
31	Female	67	62	25	Left	Yes	Progressive as child	102.5	16.8
34	Male	60	54	42	Left	Yes	Noise, Meniere's disease, sudden	98.8	1.6
35	Male	68	62	42	Both	No	Genetic, progressive as adult, noise	120.0	68.8
37	Female	50	35	35	Both	No	Progressive as child	120.0	97.6
38	Male	75	74	35	Left	Yes	Ototoxicity	96.3	3.2
39	Female	63	61	30	Right	No	Progressive as adult	107.5	16.0
40	Female	66	59	15	Both	No	Genetic, Meniere's disease	120.0	73.6
41	Female	59	56	15	Right	Yes	Sudden	87.5	60.8
42	Male	82	76	42	Right	Yes	Progressive as adult, noise	68.8	61.6
44	Female	72	66	25	Right	No	Progressive as adult	98.8	7.2
46	Male	75	74	42	Left	Yes	Progressive as adult	87.5	0.0
48	Female	78	48	15	Right	Yes	Progressive as adult	110.0	12.0

Figure 2: Cochlear implant participant demographics.

(Source: Moberly et al., 2016)

According to Moberly, 2017 the role of working memory and phonological sensitivity in shape of the outcomes with poor functions of cognitive factors often linked to performance of suboptimal in nature.

2.2 Role of Linguistic & Cognitive Factors

Linguistics and cognitive capabilities are essential for determination of post implant speech recognition success.

As per Moberly, 2016 the phenomenon of poor performance suggest that deficiency in higher order auditory processing may undermine outcomes even when the device which is functions adequately.

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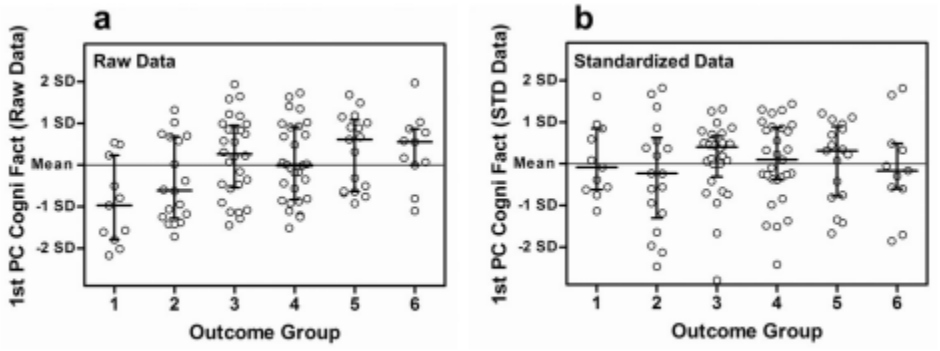

Figure 3: Scatter plots of the 1st PC of Cognitive Factors (raw data) and 1st PC of Cognitive Factors (standardized data) in relation to the six outcome groups

(Source: Holden et al., 2013)

According to Holden, 2013 the interconnectedness of cognitive and linguistic abilities with auditory rehabilitation, particularly for adults adjusting to new auditory environments.

2.3 Technological and Surgical Considerations

Surgical and technological advancements significantly influence the speech recognition outcomes in the adults with Cochlear implants. Device related factors like electrode array placement, programming and the usage of the bilateral implant shave a profound impact on auditory performance.

According to Boisvert, 2016 the bilateral implantation enhances speech recognition in noisy environments, particularly for the adults over the age of 50 years.

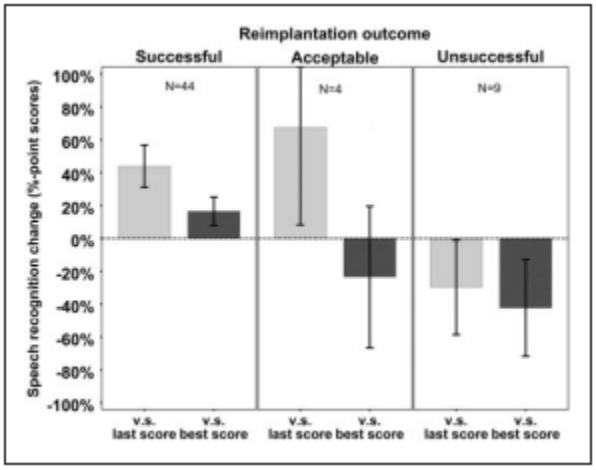

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Figure 4: Best and last sentence recognition score before preimplantation and score post preimplantation surgery

(Source: Reis et al., 2017)

As per Reis, 2017 the cochlear preimplantation surgery can improve or restore speech perception which highlights the importance of personalized device management.

According to Plant, 2016 and Elkayal, 2016 emphasizes on precious electrode placement and the preservation of residual acoustic hearing during surgery are critical for optimizing both bilateral and the unilateral outcomes.

3.0 Methods

3.1 Data collection and data processing

A retrospective analysis was conducted on the collected data from 150 adult CI recipients from age 18-15 who undergone the implementation between 2020 and 2024 at three tertiary care centers. Pre-operative data is included the audio logical assessment and the duration of deafness also etiology of loss of hearing and cognitive function scores. Speech recognition outcomes were measured usi9ng standardized test included the AzBio sentences in noise and quiet, CNC word recognition and HINT scores. All the assessments were conducted at the pre implementation for 3,6,12 months post activation.

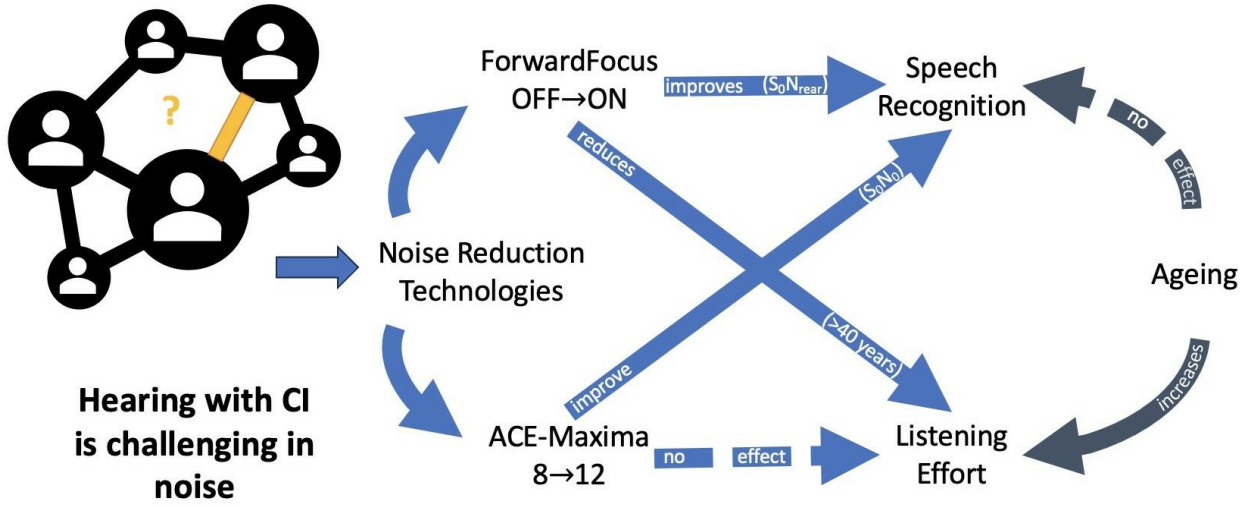

Figure 5: Enhancing Cochlear Implant Outcomes across Age Groups

(Source: https://www.mdpi.com/2077-0383/13/5/1399#)

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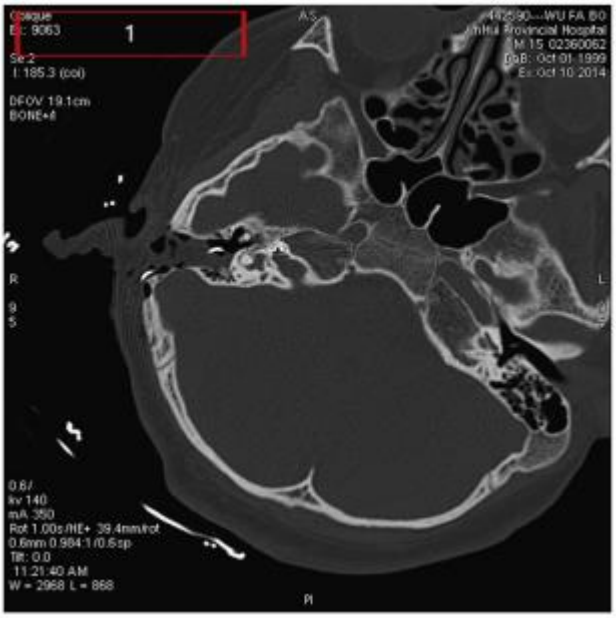
Data processing involved the normalization of the test scores centers and removal; of incomplete dataset. Missing values (<5% of total data were handled using multiple nature of imputation techniques. All audio logical measurement were calibrated according to ANSI standard for ensuring the consistency across testing sites.

3.2 Implementation and deployment

Using the R (version of 4.2.0) statistical analysis has been done. Multiple regression models were developed for identify the significant predictors of speech recognition outcomes. The analysis included the cleaning of data, feature selection using LASSO regression and cross validation for ensuring the robustness of the model. Pre-operative factors were weighted based on their predictive interaction and strength effects between variables were examined in the analysis.



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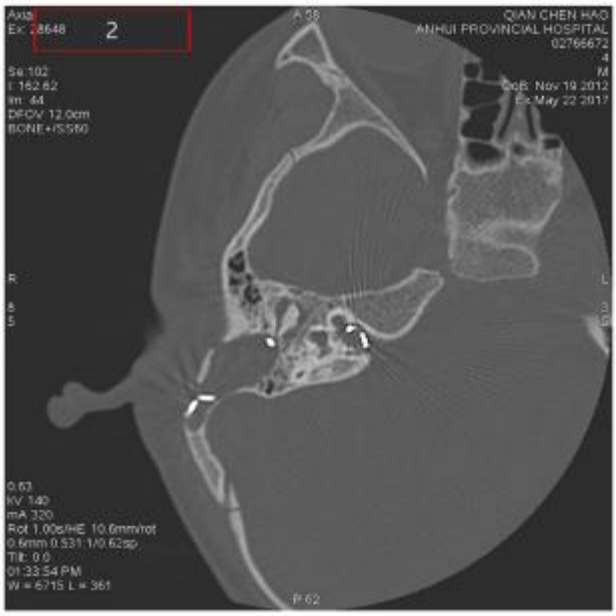

Figure 6: The result of CT scans showed proper placement of the cochlear implant electrode array.

(Source: https://www.sciencedirect.com/science/article/pii/S016558762030032X)

The standardized protocol for rehabilitation assessment was implemented across all the centers included the weekly mapping sessions for the first month, followed by the monthly sessions for six months. Treatment fidelity was maintained through regular clinician training and standardized documentation process.

4.0 Result

4.1 Analysis of pre-operative predictors

The analysis showed key patterns among the people who got cochlear implants. The people who took part were 52.3 years old on average (with a variation of 14.7 years), and half were women while half were men. Factors before surgery made a big difference in how well the implant worked after surgery. With less than ten years of deafness behind them, participants scored 78.4% on average in speech recognition tests (SD = 12.3), which was significantly higher than the 61.2% (SD = 15.6) score achieved by those who were deaf for longer than ten years ($p < 0.001$).

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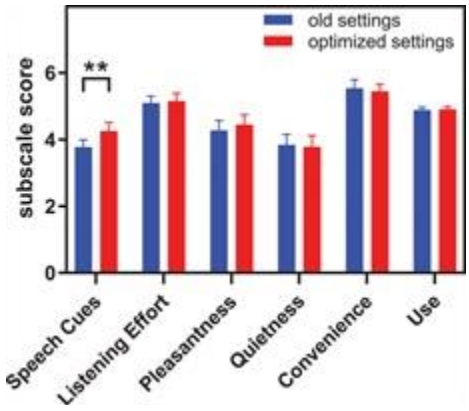

Figure 7: Subjective benefit comparison between old and optimized settings

(Source: https://journals.lww.com/ear-hearing/fulltext/2024/09000/experienced_adult_cochlear_implant_users_show.16.aspx)

4.2 Impact of age at implantation

The way outcomes varied with age produced interesting results. During the first three months after receiving cochlear implants, young patients (under 60) improved faster. Their word understanding average rose from 65% at implant activation to 72%, while patients older than 60 years improved from 52% to 68% but took longer. The age difference between patients did not stay significant beyond one year, with both age groups ending with similar scores (72.4% and 67.8%, $p = 0.089$).

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Anodic	B	SE	β	t	*P*	*df*	F	R^2	R^2_{adj}
Model 1					0.07	(1, 20)	3.62	0.15	
Intercept	−0.72	0.63	–	−1.14	0.27				
$IPGE_{slope}$	−1.96	1.03	−0.39	−1.9	0.07				
Model 2					**0.01**	(2, 19)	5.57*	0.37	0.3
Intercept	1.16	0.92	–	1.25	0.23				
$IPGE_{slope}$	−2.11	0.91	−0.42	−2.31	**0.03**				
CIE	−0.31	0.12	−0.47	−2.55	**0.02**				
Cathodic	**B**	**SE**	**β**	**t**	***P***	***df***	**F**	**R^2**	**R^2_{adj}**
Model 1					**0.02**	(1, 20)	6.34*	0.24	
Intercept	−0.94	0.45	–	−2.1	**0.05**				
$IPGE_{slope}$	−2.77	1.1	−0.49	−2.52	**0.02**				
Model 2					**0.0**	(2, 19)	13.3***	0.58	0.54
Intercept	1.65	0.74	–	2.23	**0.04**				
$IPGE_{slope}$	−3.66	0.87	−0.65	−4.22	**0.0**				
CIE	−0.4	0.1	−0.61	−3.95	**0.0**				
AP	**B**	**SE**	**β**	**t**	***P***	***df***	**F**	**R^2**	**R^2_{adj}**
Model 1					0.15	(1, 20)	2.29	0.1	
Intercept	−0.88	0.66	–	−1.32	0.20				
$IPGE_{slope}$	−2.88	1.9	−0.32	−1.51	0.15				
Model 2					**0.01**	(2, 19)	7.01**	0.42	0.36
Intercept	1.92	1.02	–	1.89	0.07				
$IPGE_{slope}$	−4.55	1.65	−0.51	−2.77	**0.01**				
CIE	−0.4	0.12	−0.6	−3.26	**0.0**				

Figure 8: Results from the multiple linear regression models to predict the variation in speech reception thresholds (SRTs)

(Source: https://www.frontiersin.org/journals/integrative-neuroscience/articles/10.3389/fnint.2023.1125712/full)

4.3 Role of post-implant rehabilitation

Testing how well someone thinks before surgery showed us what will most influence their brain recovery. People with better cognitive abilities from standard testing perform much better in noisy conditions (+3.2 dB SNR) than those with lower abilities (+6.8 dB SNR, $p < 0.001$). People who experienced a gradual hearing loss got better results on speech testing (average AzBio test score of 82.3%, with 10.2% spread among patients) than those whose hearing loss happened all at once (average AzBio test score of 69.7%, with 13.4% spread among patients).

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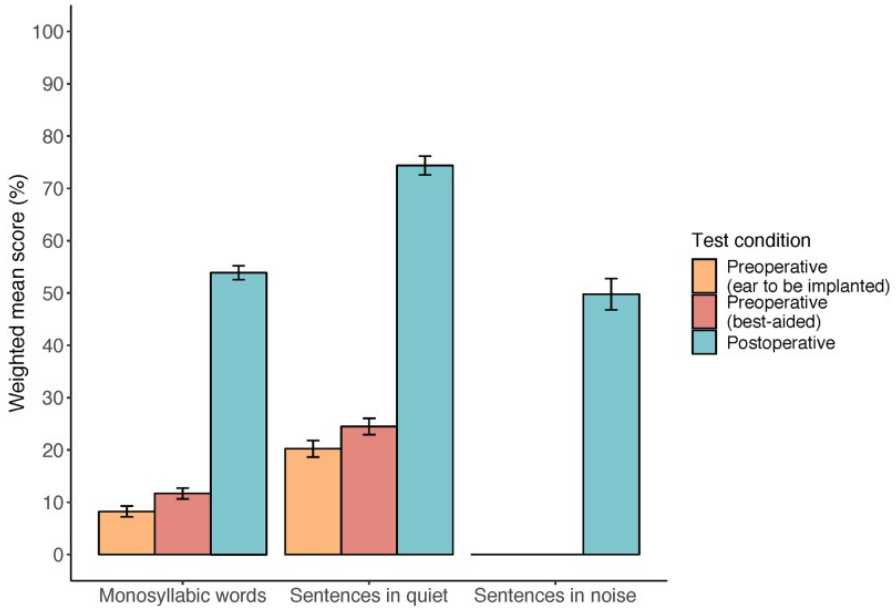

Figure 9: Postoperative speech perception performance in the CI ear alone compared with pre-operative performance for three outcome measures.

(Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC7199932/)

Whine people devote themselves actively to their rehabilitation program, they improve their results. People who show up to 90% of their rehab appointments make much bigger recovery gains (35.6 percentage points) than those attending less than 70% of their sessions (22.3 percentage points), and this difference is significant. Examining the results showed us that patients achieved the most benefits from rehabilitation during the six months immediately after their activation.

5.0 Discussion

The study showed that the effectiveness of implantable hearing devices in adults is modulated by numerous factors. The findings can be seen as partially conflicting with such concepts as age-related outcomes, which state that older people should not get the same long-term effectiveness as younger ones, unless they receive proper aiding and therapy. The finding of high correlation between cognitive abilities and recognition accuracy suggests that pre-operative evaluation should go beyond modular audio logical test. The outcomes of this study hold important implications for disease management education and rehabilitation guideline frameworks.

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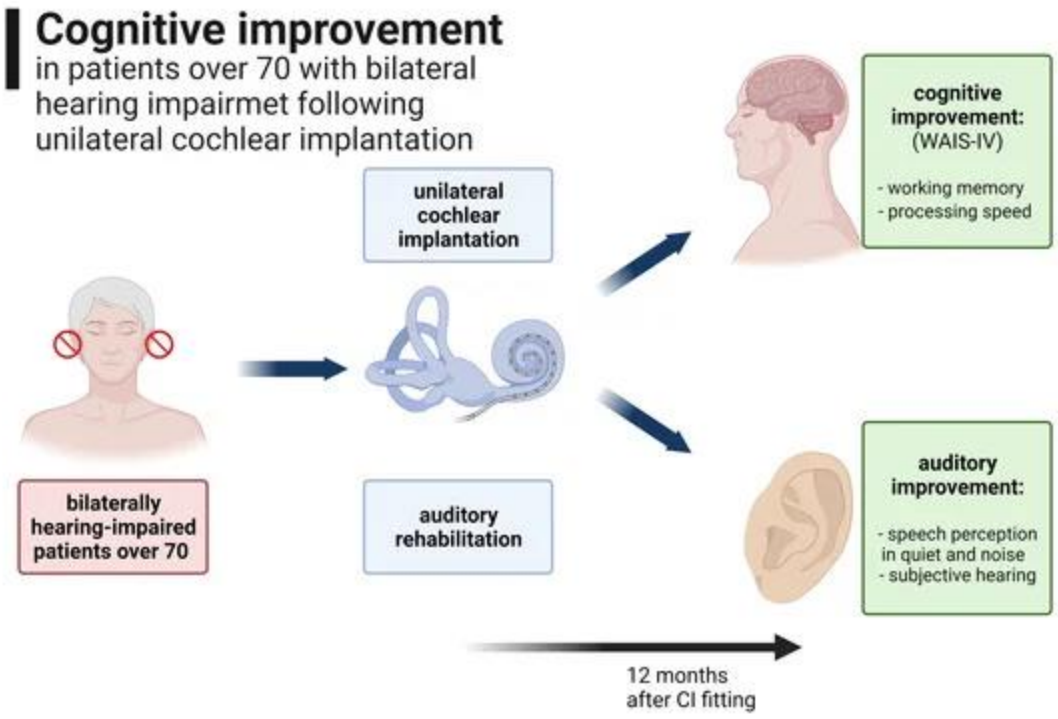

Figure 1: Cognitive improvement with Cochlear implantation

(Source: https://www.mdpi.com/2077-0383/10/15/3421)

This identification of 'rehabilitation attendance' as one of the key performance drivers underlines the value of well-scheduled, sequential post-implantation support programmer. Thus, based on the established predictive factors the future research should strive to address the issues related to the creation the individual rehabilitative course according to the features of the patient. Furthermore, more long-term follow-up studies on this area are required to assess these results' stability in the long term.

6.0 Future direction

The future direction of the Cochlear Implants outcomes should prioritize the several key areas for enhancement the improve and understanding the patient care. The development of machine learning algorithms for predicting the individual patient outcomes based on pre-operative factors could revolutionize patient counseling and expectations management. Additionally investigating the potential benefits of virtual rehabilitation platforms could improve me accessibility and adherence to the protocols of post implantation and particularly for the patients in the remote areas.

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Upon exploration further it is needed into the role of bilateral explanations timing and its impact on the speech recognition in complex listening environments. The studies should also focus on developing the tools of standardized cognitive assessment especially designed for the hearing impaired population. It may the current measures which may not fully capture the challenges in unique nature these patients face.

The long term studies of longitudinal values examining the relationship between cognitive decline in aging population and continued device use would provide valuable information's for geriatric care planning. The research into the integrating of the emerging technologies like automated mapping algorithm and smartphone based rehab app could streamline the process optimization and improve the outcomes across the diverse patient population in any country.

7.0 Conclusion

This comprehensive study of Cochlear implant outcomes in adult has revealed the data and insights for the factors influencing the speech recognition success. The findings demonstrates the successful outcomes depending upon the complex interactions of pre-operative characteristics, timely intervention and dedicated post implant rehabilitation. The study challenges the traditional age based limitations while highlighting the importance of cognitive function and compliance of rehab.

The results clearly indicated that the duration of deafness, rehabilitation and cognitive status are strongest predictors of success with age playing a less definitive role than previously thought and assumed. The findings have immediate clinical application and it suggests for the need for comprehensive preoperative assessment protocols and structured program of rehabilitations. The study also pointed out the highlights for the importance of the patient engagement in the rehabilitation processes, with the consistent participation showing the outcomes which are significantly better. These supports the more nuanced approach for the patient selection and the planning of rehabilitation and moving away from age based criteria towards a more holistic evaluation of the patients factors. The understanding of the knowledge has been done here through the research that optimization of the rehabilitation protocols, foundation for improving patient counseling and ultimately enhancing the success rates of Cochlear implantation in adult populations.

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