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Recent Advances in Cochlear Implant: A Systematic Review

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Abstract: ***Background: Cochlear implants are implantable device designed to mimic the function of a healthy inner ear. They replace the function of damaged sensory hair cells inside the inner ear to help provide clearer sound than what hearing aids can provide. The patients with cochlear implants benefit from cutting-edge sound processing technology that analyses the surrounding noise and automatically modifies the processors settings for optimum hearing. Advances in the programming of sound processing algorithm have improved the user's abilities to hear sounds other than speech such as music. This systematic review aims to provide knowledge about the recent advances in cochlear implant instrumentation and mapping strategies.***
Methods: A comprehensive literature search was conducted across major electronic databases, including PubMed, Google Scholar, Science Direct, ProQuest and Psynet. Studies published between 2012 to 2023 were included if they focused on latest technologies on cochlear implant in terms of instrumentation and mapping strategies. Relevant articles were selected, and their quality was assessed using with Preferred reporting Items for Systematic review and Meta-Analysis (PRISMA).
Results: The initial search yielded 3,102 articles, of which 12 met the inclusion criteria. The included studies highlighted the new trends in instrumentation and mapping strategies of cochlear implant. The instrumentation includes the innovative technologies such as SCAN, wireless technology, sound processors, smart application for iPhone and android users and development in electrodes and surgical techniques. In considering, the mapping strategies, evaluating T level, C level and dynamic range which assisted in studying comfortability level of cochlear implant while facing challenging environment composed of speech and other sounds.
Conclusion: The findings of this systematic review underline the significance of recent development in cochlear implant. The results from all 12 articles had shown tremendous improvement in recognizing speech and improving quality of life for individuals with sensorineural hearing loss. In addition to that all literature had shown that these new technologies made the user's seamless and effortless while handling the cochlear implant.
Keywords: Cochlear Implant, Speech Perception, Sound Processor, Surgery, Electrode Array, Mapping.

I. INTRODUCTION

Sensorineural hearing loss is common type of hearing loss that occurs around the world. According to World Health Organization by 2050 nearly 2.5 billion people are projected to have some degree of hearing loss and at least 700 million will require hearing rehabilitation. The cochlear implant serves a solution for sensorineural deafness and has created a paradigm in the treatment of sensorineural hearing loss. It will have a great impact in brief time. In less than four decades, the cochlear implant has progressed from the first attempt to elicit hearing via direct electrical stimulation of the auditory nerve to a commercially available device that has restored varying degrees of hearing to thousands of deaf patients.The CI has improved and enhanced to restore hearing through years with the research and developmental activities of manufacturers and audiologist. The sound processor is the one that has undergone continuous modification as it started from the bodyworn type to a single unit processor. Signal processing strategies have seen changes over time which started with simultaneous multichannel analog stimulation to channel specific sequential stimulation that resulted in power consumption and better hearing experience by the CI users. Due to recent advancement, there are MRI compatible implant magnet would assist in trouble free MRI procedures without the need for the surgical removal of the magnet.

A. Need For The Study

Cochlear implant is the most powerful sensory device which helps in reestablishing hearing. CI has undergone modifications in surgical as well as in terms of technology. In considering, speech perception CI is able to deliver best outcome in research and development of sound processor, electrode array, microphone etc. Hence it is required to review through various studies conducted around the world.

II. METHEDOLOGY

A. Aim

To systematically review the outcomes of literatures that used in recent advances in cochlear implant.

B. Objectives

1) To provide a thorough overview of recent advances in cochlear implant.
2) To understand the patient's experience derived from modern technologies in cochlear implant.
3) To provide insight about significance of cochlear implant

C. Review Question

The current review of studies was performed with the following review question: "What are the recent advances in cochlear implant instrumentation and mapping strategies?"

1) *Criteria For Inclusion Of Literature*

a) Literature must be from 2012 to 2023.
b) Studies available in English.
c) Studies contained original data addressing the review/clinical questions.

2) *Criteria For Exclusion Of Literature*

a) Repeated or duplicate studies.
b) Studies with unclear findings.
c) Studies which are not within inclusion criteria.

D. Search Process

The review was conducted in accordance with Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) standards. Key words like "Cochlear Implant, Speech Perception, Sound Processor, Surgery, Electrode Array, Mapping were the search terms. These search terms were used to look up literature across several databases. PubMed, Google Scholar, Science Direct, ProQuest and PsyNet databases were used to find out the related articles for the review. The PRISMA flow chart has four steps: discovering the articles, screening the articles that have been found, determining their eligibility and choosing the articles for the study. These concluding articles were chosen as qualitative studies that met the requirements for inclusion in the current investigation.

E. Data Extraction

The titles, abstracts and/or research methods that the search techniques returned were screened to identify the studies that met the inclusion and exclusion criteria. The full text of the potential studies was then obtained and reviewed to ascertain their eligibility. A table created for the pre study was used to retrieve the data from the chosen research. The following information was extracted: study population, methodology, participant demographics, evaluation methods and treatment outcome. Data on the eligible articles that met the inclusion and exclusion criteria were also collected including information on the year of publication, kind of publishing, study design, research type, research emphasis, study origin and author details with affiliation.

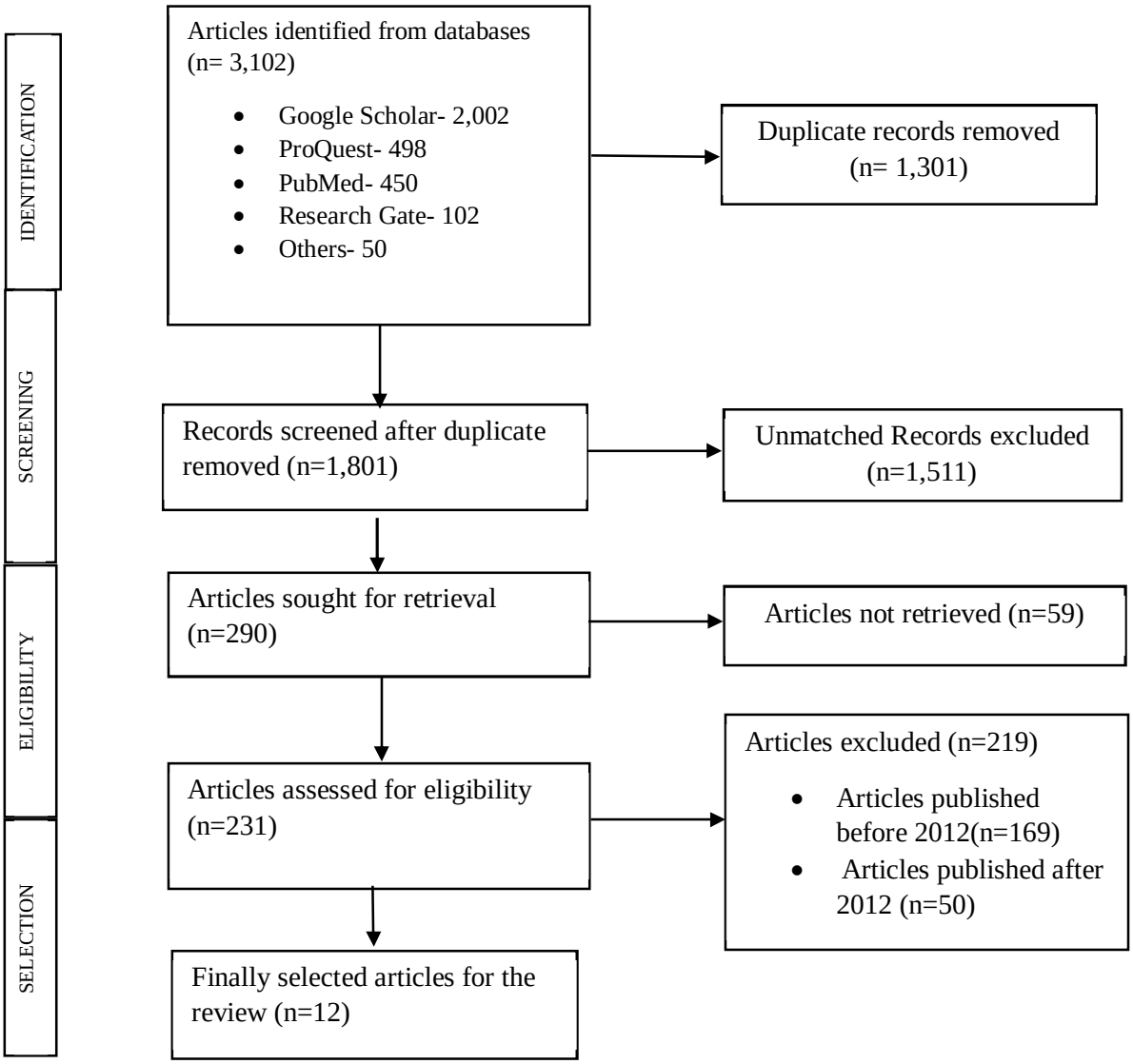
III. RESULT AND DISCUSSION

A. Selection Of Literature for Systematic Review

Identification of the articles relevant to the current topic was important step and using key words to the different electronic databases, 3102 records were identified. Different database included Google scholar (n=2002), ProQuest (n=498), PubMed (n=450), Research Gate (n=102) and others (n=50). From the total identified articles (3,102), duplicate articles (1,301) were excluded and remaining 1,801 articles were screened for the study. The articles (1,511) that did not match the review topic were also excluded. Remaining 290 articles were taken into consideration for further process and 59 articles were not able to be retrieved and were also not included. 231 articles were assessed for eligibility for inclusion in the current review. Articles that were published (169) earlier than 2012 were also not included. Article published after 2012 (n=50). Finally, only 12 articles fully matched our eligibility criteria and were selected for the study.

These twelve articles are the latest research papers that are published in different journals of audiology between 2012 to 2023. These all papers include the recent advances in cochlear implant instrumentation and mapping strategies.

Figure 1: Shows the Diagram that illustrates the PRISMA



IV. STUDY DESIGN AND CHARACTERISTICS

Papers selected for the current review were all pre and post-test research design depending on comparative, observational, training survey and experimental study (Table 1). What are the recent advances in cochlear implant instrumentation and mapping strategies are listed in Table 1. Zhou, Wang, Zheng, Yu and Meng (2020) included 19 participants in which 11 were 2 weeks experienced CI users and 8 were 5-10 min CI users. Ceulaer, Pascoal ,Vanpoucke, Govaerts (2017), included a group of 13 adult CP900 recipients participated. Chang, Jung, Sun, Hung, Hsu, Jen, Chiu, Ting; Yu, Hui, Wu, Hung (2022), included 20 adult CI recipients. Shaul, Chanan, Weder, Stefan, Tari, Sylvia, Marc, Leary, Stephen, Briggs, Robert (2020), included all patients receiving the CI532 implant before June 2018. McJunkin, Jonathan, Durakovic, Nedim, Herzog, Jacques, Buchman, Craig (2018), included 117 adult CI patients.

Valimaa, Kunnari, Sar, Aarnisalo, Dietz, Aarno, Hyvarinen, Antti, Laitakari, Jaakko, Mykkanen, Sari, Rimmanen, Satu,Salonen, Jaakko, Sivonen, Ville, Tennila, Tanja, Tsupari, Teija, Vikman, Sari, Virokannas,Nonna,Nevala, Tolonen, Kaisa, Tuohimaa, Krista, Lopponen, Heikki (2022), included the participants comprised 56 children: 28 children in the BiHA group and 28 children in the BiCI group. Kurz, Rak, Hagen (2022), included twenty adult SONNET users were fitted with the SONNET 2 audio processor was sample size. Kolberg, Sheffield (2015), included total of 11 adults with Advanced Bionics CIs were recruited. MacPhail, Connell, Totten, Gray, Pisoni, Yates, Nelson (2022), included slim lateral wall electrode (SLW) 52 and patients with slim modiolar electrode (SME) 37. Dincer, Alessandro, Ballantyne, Portanova, Greco, Mancini (2022), included Eleven post lingually deafened bimodal listeners. Perreau, Tyler, Frank, Watts, Mancini (2021), included 14 using the ReSound Tinnitus Relief app to evaluate its acceptability and effectiveness in reducing their tinnitus. Incerti, Ching, Hou, Buynder, Flynn and Cowan (2018), included 161 children. Figure 1: shows the diagram that illustrates the PRISMA (Moher, Liberati, Tetzlaff & Altman, (2020), process of identification, screening and selection of the articles for the present study.

Table 1: Shows that the recent advances in cochlear implant instrumentation and mapping strategies.

AUTHOR/ YEAR/ COUNTRY	TITLE OF THE JOURNAL/ BOOOK/ CONFERENCE	PAPER TITLE	AIM OF STUDY	STUDY DESIGN	STUDY SAMPLE SIZE/ TYPE	TECHNIQUE USED	DURATION/ TRAINING PERIOD OF EACH TECHNIQUE	ASSESSMENT TOOL	FINDINGS
Huali Zhou1, Ningyuan Wang2, Nengheng Zheng3, Guangzheng Yu1* and Qinglin Meng 21 April 2020 CHINA	Frontiers in Neuroscience	A New Approach for Noise Suppression in Cochlear Implants: A Single-Channel Noise Reduction Algorithm	To study CI users experience that face challenges in common acoustic environments than their normal hearing peers	Experimental design	Experiment 1: Leven experienced CI users Experiment 2: eight experienced CI users	Experiment1 : Questionnaire Experiment 2: Speech Reception Threshold	Experiment1: 2 weeks Experiment 2: 5-10 min	Experiments	Speech intelligibility in stationary speech-shaped noise can be significantly improved with eVoice.
Geert De Ceulaer 1 , David Pascoal , Filiep Vanpoucke, Paul J Govaerts 2017 NOVEMBER BELGIUM	International Journal of Audiology	The use of cochlear' s SCAN and wireless microphones to improve speech understanding in noise with the Nucleus6® CP900 processor	To understand the (1) use of an adaptive directional microphone (SCAN mode) and (2) wireless connection to MiniMic1 and MiniMic2 wireless remote microphones	Experimental design	A group of 13 adult CP900 recipients participated.	Speech Reception Threshold	Duration of CI users 8-15 years	Noise presenting speakers , speech presenting speakers	SCAN and MiniMic1 improved performance compared to the standard microphone with a median improvement in SRT of 2.7-3.9 dB for SCAN at 1 m and 3 m, respectively, and 4.7-10.9 dB for the MiniMic1. MiniMic1 improvements were significant. MiniMic2 showed an improvement in SRT of 22.2 dB compared to 10.0 dB for MiniMic1 (3 m).
Chang, Chan-Jung; Sun, Chuan-Hung; Hsu, Chuan-Jen; Chiu, Ting; Yu, Szu-Hui; Wu, Hung-Pin 2022	Journal of the Chinese Medical Association	Cochlear implant mapping strategy to solve difficulty in speech recognition	The aim of this study was to report a mapping strategy based on different target-aided hearing	Single-subject design	20 Adult CI recipients	Questionnaire & word and sentence discrimination assessment	2 weeks	Sound field audiometry booth	The correlation between audiometry results and word and sentence recognition was not high. CIs performed best at an audiometry threshold between 25 and 35 dB.

CHINA			thresholds to achieve optimal speech recognition and maximize functional outcomes.						
Shaul, Chanan; Weder,Stefan; Tari, Sylvia; Gerard, Jean-Marc; O'Leary, Stephen J; Briggs, Robert J. JUNE 2020 AUSTRALIA	*Otology & Neurotology*	Slim, Modiolar Cochlear Implant Electrode: Melbourne Experience and Comparison with the Contour Perimodiolar Electrode	To describe the tip fold over rate, scalar localization, and speech perception outcomes of the CI532 Slim Modiolar Electrode	Experimental design	All patients receiving the CI532 implant before June 2018	Comparison made with previous experience with the Contour perimodiolar electrode (CI512)	At 3&12 months postoperative	Operative report details, electrode position as determined by X-ray and cone beam computed tomography.	One hundred twenty-five CI532 devices were implanted in adults and 69 in children. Electrode tip fold-over occurred in eight adult cases and none among children (4.1%). Cone beam CT scans of 120 out of 125 adult patients confirmed scala tympani (ST) position in all but one case where the electrode had been placed into scala vestibuli. There were no translocations from ST to scala vestibuli. This compares favorably with the CI512 translocation rate of 17%. Speech perception outcomes demonstrated good performance with mean preop phoneme scores of 16.2% (±13) increasing to 64.2% (±14) and 71.6 (±16) 3 and 12-months postop, respectively. Compared with a matched group of CI512 recipients, CI532 recipient phoneme scores were significantly higher 3 and 12-months postop by 4 and 7%, respectively.
McJunkin, Jonathan L; Durakovic, Nedim; Herzog,Jacques; Buchman,Craig A January 2018 Washington	Otology & Neurotology	Early Outcomes with a Slim, Modiolar Cochlear Implant Electrode Array	To describe outcomes from cochlear implantation with a new, slim modiolar electrode array.	Retrospective cohort study.	Adult cochlear implant candidates	Cochlear implantation with CI532 (Cochlear Corp).	3 months postoperative	Pre- and postoperative speech perception scores, operative details, and postoperative computed tomography (CT) reconstructions of array location.	One hundred seventeen patients are implanted to date. There were eight tip rollovers identified with intraoperative x-ray and resolved with reinsertion. An additional rollover was identified on postoperative CT. CT reconstructions in 17 of 23 patients showed complete scala tympani placement with a wrap factor of 58% (range 53–64%) and a mean insertion angle of 406 degrees (range 360–452 degrees). Three implants demonstrated array translocation with electrodes in the scala vestibuli. Consonant-nucleus-consonant word scores improved from 10% preoperatively to 48% at 3 months postoperatively. Pure-tone thresholds were preserved postoperatively in 37 to 52% of patients across frequencies from 250 to 4000 Hz. Functional pure-tone thresholds (≤80 dB) were recorded in 9 to 25% of patients.
Välimaa, Taina T.Kunnari, Sar,Aarnisalo, Antti A. Dietz, Aarno, Hyvärinen, Antti, Laitakari,Jaakko; Mykkänen, Sari; Rimmanen, Satu; Salonen, Jaakko; Sivonen, Ville; Tennilä, Tanja; Tsupari, Teija; Vikman, Sari; Virokannas, Nonna; Laukkanen-Nevala, Päivi; Tolonen, Anna-Kaisa; Tuohimaa, Krista; Löppönen,	*Ear and Hearing The official journal of the American auditory society*	Spoken Language Skills in Children with Bilateral Hearing Aids or Bilateral Cochlear Implants at the Age of Three Years	Early hearing aid (HA) fitting and cochlear implants (CIs) aim to reduce the effects of hearing loss (HL) on spoken language development.	An accelerated prospective longitudinal design was implemented	The participants comprised 56 children: 28 children in the BiHA group and 28 children in the BiCI group.	Spoken Language Test	At the age of 3 years	Children's spoken language skills were evaluated with a comprehensive assessment battery focused on language comprehension, receptive and expressive vocabulary, and phonolo	At the age of 3 years, 50%–96% of children with HL performed 1 SD or more below the mean of the normative sample of age-peers with NH in spoken language skills, depending on the language domain. Receptive vocabulary and phonological skills were the most vulnerable language domains. In receptive vocabulary, 82% of the children in the BiHA group and 50% of the children in the BiCI group scored 1 SD or more below the normative mean. The BiHA group was 4.4 times more likely to have poorer receptive vocabulary than the BiCI group. In phonological skills, 96% of children in the BiHA group and 60% of the children in the BiCI group scored 1 SD or more below the normative mean. The BiHA group was 18.0 times more likely to have poorer phonological skills than the BiCI group. The analysis of covariance models showed that unaided pure-tone average, PTA0.5–4 kHz, had a significant effect on spoken language comprehension in the BiHA group. For the BiCI group, age at HL diagnosis and age at CI activation had a significant effect on expressive vocabulary. High maternal level of education had a significant effect on language comprehension

Heikki *January/February 2022* Finland								gical skills	and expressive vocabulary and female gender on phonological skills
Anja Kurz, Kristen Rak, Rudolf Hagen September 15,2022 Germany	PLOS ONE	Improved performance with automatic sound management 3 in the MED-EL SONNET 2 cochlear implant audio processor	To evaluate if using these features improves speech perception in noise, subjective listening effort, and sound quality.	Prospective longitudinal study	Twenty adult SONNET users were fitted with the SONNET 2 audio processor was sample size	The Audio Processor Satisfaction Questionnaire (APSQ)	≥ 6 months experience using the MED-EL SONNET audio processor	Speech perception tests and subjective ratings	Subjects strongly preferred the SONNET 2 configurations over the SONNET configuration
Elizabeth R. Kolberg,* Sterling W. Sheffield, Timothy J. Davis, Linsey W.Sunderhaus, and René H. Gifford . 2015 Jan, USA	Journal of American Academy of Audiology	Cochlear Implant Microphone Location Affects Speech Recognition in Diffuse Noise	To (1) measure physical output for the T-Mic as compared with the integrated behind-the-ear (BTE) processor mic for various source azimuths, and (2) to investigate the effect of CI processor mic location for speech recognition in semi-diffuse noise with speech originating from various source azimuths as encountered in everyday communicative environments.	A repeated-measures, within-participant design was used to compare performance across listening conditions	A total of 11 adults with Advanced Bionics CIs were recruited	Physical acoustic output was measured on a Knowles Experimental Mannequin for Acoustic Research (KEMAR) for the T-Mic and BTE mic, with broadband noise presented at 0 and 90° (directed toward the implant processor).	6 Months	Knowles Experimental Mannequin for Acoustic Research (KEMAR)	The integrated BTE mic provided approximately 5 dB attenuation from 1500–4500 Hz for signals presented at 0° as compared with 90° (directed toward the processor). The T-Mic output was essentially equivalent for sources originating from 0 and 90°. Mic location also significantly affected sentence recognition as a function of source azimuth, with the T-Mic yielding the highest performance for speech originating from 0°.
Margaret E macphail,Nathan T Connell,Douglas J Totten, Mitchell T Gray, David Pisoni, Charles W Yates, Rick F Nelson May 2022 USA	Journal of otolaryngology Head Neck and surgery	Speech Recognition Outcomes in Adults with Slim Straight and Slim Modiolar Cochlear Implant Electrode Arrays	To compare differences in audiologic outcomes between slim modiolar electrode (SME) CI532 and slim lateral wall electrode (SLW) CI522 cochlear implant recipients.	Retrospective cohort study.	SLW (n = 52) and patients with SME (n = 37	Speech recognition test		AzBio sentence.	Cochlear implantation with SLW and SME provides comparable improvement in audiologic functioning. SME does not exhibit superior speech recognition outcomes when compared with SLW.

Hilal Dincer, D'Alessandro, Deborah Ballantyne, Ginevra Portanova , Antonio Greco, Patrizia Mancini April 2022 Turkey and Italy	Elsevier	Temporal coding and music perception in bimodal listeners	To evaluate music perception in relation to LF pitch perception and temporal coding, specifically in people with bimodal stimulation as a promising approach to improve Spectro-temporal sensitivity in CI listeners.	Experimental design	Eleven post lingually deafened bimodal listeners	The music perception protocol was based on three audio files in the genres of Classical, Jazz and Soul music and a music quality questionnaire regarding four subjective aspects: Clarity, Pleasantness, Naturalness and General Quality of Sounds.	The mean duration of CI use was 38 months	Harmonic Intonation (HI) and Disharmonic Intonation (DI)	CI alone and bimodal findings showed statistically significant differences for both temporal coding and music perception. DI findings showed statistically significant correlations with music quality ratings ($p<0.05$).
Ann E Perreau , Richard S Tyler , Victoria Frank , Alexandra Watts 2, Patricia C Mancini 2021 Sep 10 USA	American journal of audiology	Use of a Smartphone App for Cochlear Implant Patients with Tinnitus	The use and acceptability of a smartphone app to help CI patients with tinnitus.	Experimental design	14	Participants completed a laboratory trial (n = 19) and an at-home trial (n = 14) using the ReSound Tinnitus Relief app to evaluate its acceptability and effectiveness in reducing their tinnitus.	2 weeks	Smartphone App	All 14 participants had a positive experience with the app during the at-home trial on tests of sound therapy acceptability, effectiveness, and word recognition.
Paola V Incerti,1,2,3 Teresa YC Ching,1,2 Sanna Hou,1,2 Patricia Van Buynder,1,2 Christopher Flynn,1 and Robert Cowan2 2018 May Australia	International journal of audiology	Programming characteristics of cochlear implants in children: effects of etiology and age at implantation	Effects of etiology and age at implantation on changes in threshold (T) levels, comfortable (C) levels and dynamic range (DR) for cochlear implants (CIs) in children over the first five years of life	Longitudinal Study	161 children	Changes in threshold (T) levels, comfortable (C) levels and dynamic range (DR) for cochlear implants (CIs) in children over the first five years of life	6 months post activation of CI	Threshold level, comfortable level and dynamic range	Children with neural and structural cochlear lesions had higher T-levels and C-levels as compared to those without these conditions. Parameter settings varied from manufacturer's defaults more often in the former than in the latter group. Investigation of the effect of age at implantation for children without neural and structural cochlear lesions showed that those implanted at ≤12months of age had higher T-levels and narrower DR at 6-months post-activation, as compared to the later-implanted group. For both early- and later-implanted groups, the C-levels at 6-months post-activation were lower than those at age 3 and 5 years. There were no significant differences in T-levels, C-levels, or DR between age 3 and 5 years.

Table 2: Shows Overall Study Findings Of Recent Advances In Cochlear Implant Instrumentation And Mapping Strategies

POPULATION STUDIED	NUMBER OF PAPERS	TOTAL NUMBER OF PARTICIPANTS	PERCENTAGE %	OVERALL FINDINGS
ENGINEERS	1	19	8.3	Speech intelligibility in stationary speech-shaped noise can be significantly improved with eVoice
COMPANY RELATED TO HEARING	1	13	8.3	SCAN and MiniMic1 improved performance compared to the standard microphone with a median improvement in SRT of 2.7-3.9 dB for SCAN at 1 m and 3 m, respectively, and 4.7-10.9 dB for the MiniMic1. MiniMic1 improvements were significant. MiniMic2 showed an improvement in SRT of 22.2 dB compared to 10.0 dB for MiniMic1 (3 m).
HOPITALS & RESEARCH CENTERS	8	521	66.6	The slim modiolar, CI532 electrode has provided very reliable ST position with a low rate of tip fold over. A trend toward better speech perception scores in CI532 compared with CI512 was observed.
				CI532 array insertion results in consistent scala tympani location and provides expected audiologic performance. Initial hearing preservation results are not consistent with current electro-acoustic arrays.
				At the age of 3 years, especially receptive vocabulary and phonological skills caused difficulties for children with HL Showing also considerable individual variation. Children with bilateral HAs seemed to be more likely to have poorer receptive vocabulary and phonological skills than children with bilateral CIs. A variety of factors was associated with outcomes in both groups. Close monitoring of spoken language skills of children with HL is important for ensuring similar opportunities for all children with HL and timely intervention, when needed
				The new front-end features implemented in the SONNET 2 audio processor objectively improve speech perception in noise. Subjects preferred the SONNET 2, over the SONNET, in the presence of stationary and transient noise.
				These results have clinical implications for (1) future implant processor design with respect to mic location, (2) mic settings for implant recipients, and (3) execution of advanced speech testing in the clinic.
				Cochlear implantation with SLW and SME provides comparable improvement in audiologic functioning. SME does not exhibit superior speech recognition outcomes when compared with SLW.
				CI performance with the best perception relies on a balance between minimizing the hearing threshold and maximizing the dynamic range while maintaining an appropriate comfort level, which was achieved when the target hearing threshold was set at 25–35 dB in this study.
				Sound therapy using a smartphone app can be effective for many tinnitus patients using CIs. Audiologists should recommend a sound and a level for tinnitus masking that do not interfere with speech perception.
AUDIOLOGIST	1	11	8.3	CI alone and bimodal findings showed statistically significant differences for both temporal coding and music perception.
LABORATORY	1	61	8.3	Etiology and age at implantation had significant effects on T-levels and C-levels

V. OUTCOMES

Table 3: Shows outcomes of CI instrumentation

AUTHOR & YEAR	OUTCOMES
Zhou et.al, (2020)	Speech intelligibility in stationary speech-shaped noise can be significantly improved with eVoice.
Ceulaer et.al, (2017), Shaul et.al, (2020), Kurz et.al, (2022) and Connell et.al, (2022)	SCAN, MiniMic2, SONNET 2 audio processor and slim modiolar CI532 electrode assisted in improving speech perception scores as well as speech recognition threshold.
McJunkin et.al, (2018)	CI532 array insertion results in consistent scala tympani location and provides expected audiologic performance. Initial hearing preservation results are not consistent with current electro-acoustic arrays.
Valimaa et.al, (2022)	At the age of 3 years, especially receptive vocabulary and phonological skills caused difficulties for children with HL showing also considerable individual variation. Children with bilateral HAs seemed to be more likely to have poorer receptive vocabulary and phonological skills than children with bilateral CIs. A variety of factors was associated with outcomes in both groups. Close monitoring of spoken language skills of children with HL is important for ensuring similar opportunities for all children with HL and timely intervention when needed.
Kolberg and Sheffield (2015)	These results have clinical implications for (1) future implant processor design with respect to mic location (2) mic settings for implant recipients and (3) execution of advanced speech testing in the clinic.
Dincer et.al, (2022)	CI alone and bimodal findings showed statistically significant differences for both temporal coding and music perception.
Perreau et.al, (2021).	Sound therapy using a smartphone app can be effective for many tinnitus patients using CIs. Audiologists should recommend a sound and a level for tinnitus masking that do not interfere with speech perception.

Table 4: Shows outcomes of Mapping Strategies

AUTHOR & YEAR	OUTCOMES
Chang et.al, (2022)	CI performance with the best perception relies on a balance between minimizing the hearing threshold and maximizing the dynamic range while maintaining an appropriate comfort level, which was achieved when the target hearing threshold was set at 25–35 dB in this study.
Incerti et.al, (2018)	Etiology and age at implantation had significant effects on T-levels and C-levels.

VI. SUMMARY AND CONCLUSION

The current systemic review focussed on recent trends in instrumentation and mapping strategies of cochlear implant. The instrumentation includes the innovative technologies such as SCAN, wireless technology, sound processors, smart application for iPhone and android users and development in electrodes and surgical techniques. In considering, the mapping strategies, evaluating T level, C level and dynamic range which assisted in studying comfortability level of cochlear implant while facing challenging environment composed of speech and other sounds. Through past decades cochlear implant has evolved to maximally benefit over wide range of population. Overall, due to the advent of innovative technologies and studies conducted on it helps in spreading awareness to individuals with hearing loss and among healthcare professionals.

A. Limitations Of The Study

1) Less number of articles taken.
2) Less number of articles taken related to mapping strategy.
3) Limited study in relation to child population who use CI.

B. Implication Of The Study

1) Study can be administered on Indian Population or any one country.
2) The study could be done more on mapping strategy.
3) More studies can be included for systematic review to obtain good statistical evidence.

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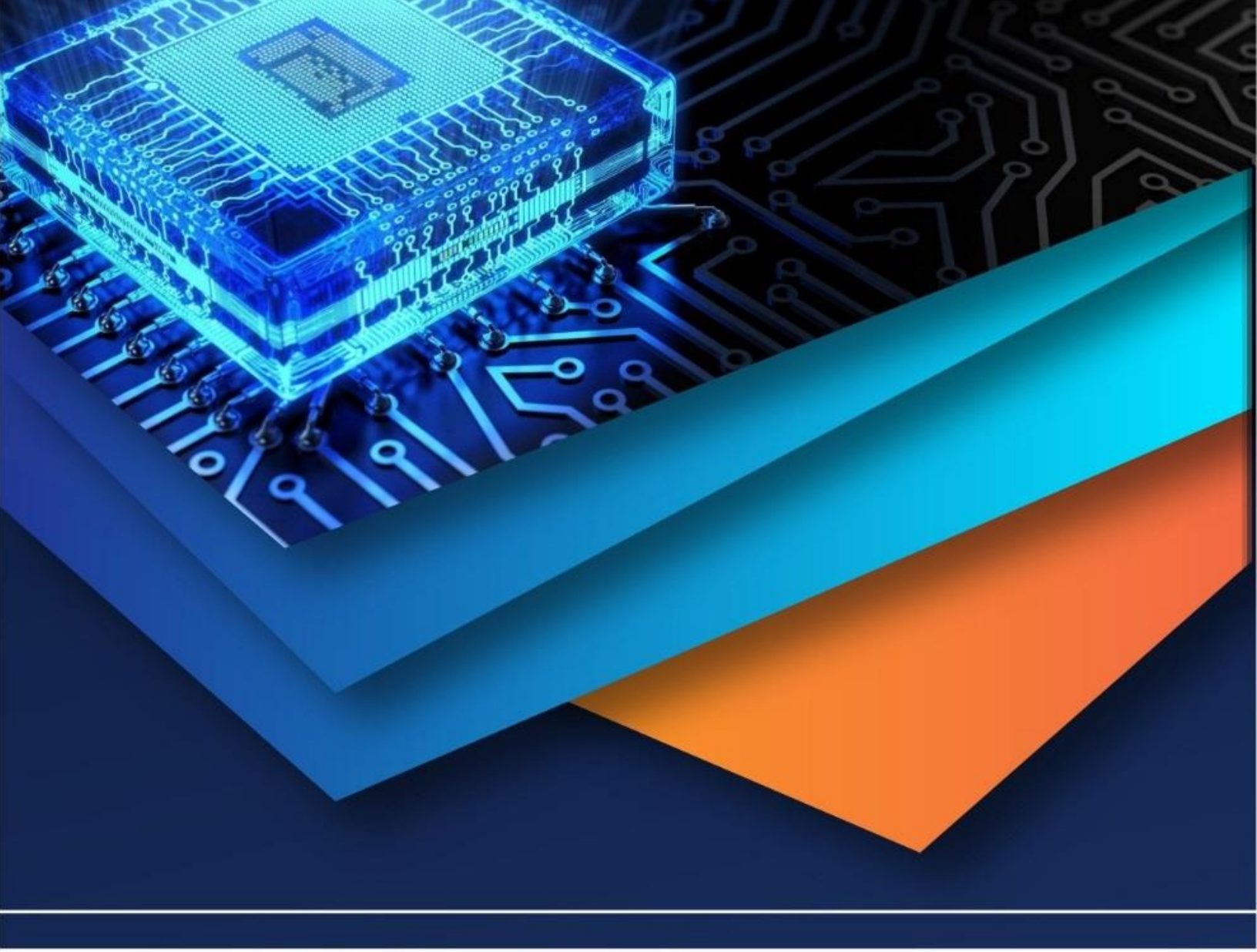

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