CONSENSUS STATEMENTS ON COCHLEAR IMPLANT MAPPING PROCEDURES FROM THE PERSPECTIVE OF AUDIOLOGISTS IN INDIA

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JUNE, 2026

CERTIFICATE

This is to certify that this dissertation entitled **"Consensus statements on cochlear implant mapping procedures from the perspective of audiologists in India"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science **(Audiology)** of the student with Registration Number **P01II24S023043**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **" Consensus statements on cochlear implant mapping procedures from the perspective of audiologists in India "** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **" Consensus statements on cochlear implant mapping procedures from the perspective of audiologists in India "** is the result of my own study under the guidance of Dr. Geetha C, Associate Professor in Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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~S H U B H A M~

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List of Frequently Used Abbreviations

CI - Cochlear Implant

USL - Upper Stimulation Level

MCL - Most Comfortable Level

LSL - Lower Stimulation Level

eCAP - Electrically Evoked Compound Action Potential

eSRT - Electrically Evoked Stapedial Reflex Threshold

eABR - Electrically Evoked Auditory Brainstem Response

NRT - Neural Response Telemetry (Cochlear Ltd.)

NRI - Neural Response Imaging (Advanced Bionics)

THR - Threshold (Stimulation Level)

PTA - Pure Tone Audiometry

ANSD - Auditory Neuropathy Spectrum Disorder

EAS - Electro-Acoustic Stimulation

ALD - Assistive Listening Device

MRI - Magnetic Resonance Imaging

CT - Computed Tomography

VRA - Visual Reinforcement Audiometry

BOA - Behavioural Observation Audiometry

Abstract

Cochlear Implant (CI) mapping is widely recognised as a primary determinant of post-implantation outcomes, yet it remains the least standardised aspect of CI rehabilitation. Considerable variability exists across clinicians and centers in India regarding programming procedures, from pre-switch on readiness assessment through long-term follow-up. The present study aimed to develop evidence-based and contextually relevant guidelines for CI mapping procedures for use by audiologists practising in India. A survey-based consensus methodology was employed, wherein a structured questionnaire addressing both general and manufacturer-specific CI mapping practices was developed following a comprehensive literature review and expert proofreading. The questionnaire was distributed to experienced CI audiologists across India, and responses were collected from 20 participants until data saturation was achieved. Data were analysed using frequency and percentage analysis, and consensus statements were derived from areas of agreement among the participants. The expert's recommendations varied with regard to activation days post-surgery. Behavioural measures were identified as the primary method for setting the stimulation levels, with eCAP and eSRT serving as supportive objective measures. Default programming parameters were generally maintained across manufacturers, with modifications made only when clinically indicated. Follow-up was recommended within 2-4 weeks of switch-on, with 1-5 sessions during the first quarter, while loudness balancing was emphasised for bilateral and bimodal CI users. A total of 66 consensus statements were generated and integrated into a 12-step CI mapping protocol adaptable to recipient age, clinical condition, and device manufacturer.

Keywords: cochlear implant, mapping, programming guidelines, consensus statements, India, switch-on, stimulation levels, electrode impedance

Chapter I

Introduction

Cochlear implantation considered an effective intervention for individuals with severe to profound hearing loss (Satish Nair, 2014). A Cochlear Implant (CI) consists of external components that capture sound and transmit it to an internal receiver, which is connected to a tonotopically organised electrode array in the cochlea. The array stimulates corresponding auditory nerve neurons with electrical currents, allowing the brain to perceive sound (Saleh et al., 2013). For meaningful listening to develop, the device needs to be carefully adjusted, known as mapping or programming. This process is performed using specialised software and a hardware interface connected to the speech processor and typically guided by the recipient's behavioural responses (Vaerenberg et al., 2014b)

The implant functionality is assessed intraoperatively using electrophysiological and biophysical evaluations, including measurements of electrode impedance, electrically evoked compound action potential (eCAP), electrically evoked stapedial reflex threshold (eSRT), and electrically evoked auditory brainstem responses (eABRs). In addition, subjective patient responses may also be used as part of the evaluation (Alzhrani et al., 2024). Once intraoperative testing is completed, the process proceeds to the next stage: the initial switch-on and mapping.

The switch-on process begins with the establishment of mapping parameters, most notably the lower and upper stimulation levels for each electrode, hereafter referred to as LSL and USL, respectively. Following electrode impedance measurements, programming professionals measure the LSL and USL for the electrical signals from the CI (Wolfe & Schafer, 2015). However, approaches to setting these levels vary: each centre often develops its own protocols, and even within the same

centre, individual clinicians may adopt different practices. Additional variation arises depending on whether the recipient is a child or an adult. Furthermore, differences exist across manufacturers regarding programming software, user interfaces, and device-specific features used to determine LSL and USL, resulting in heterogeneous programming approaches (Browning et al., 2020; Vaerenberg et al., 2014b).

Among the diverse programming approaches, the determination of the LSL is typically carried out behaviorally using age-appropriate conditioning and observation methods in children, and standard audiometric techniques in adults (Banda González et al., 2017). Objective measures may also be employed, including eCAP, eSRT, and, in some cases, eABR (Hodges et al., 1997; Walkowiak et al., 2011; Wolfe et al., 2017).

Clinicians often rely on evoked potentials, particularly eCAP thresholds, as a preliminary guide for setting LSLs and USLs. However, these values are not regarded as fixed points; instead, they serve as initial references while setting the map and are modified subsequently based on the recipient's loudness perception (Allam & Eldegwi, 2019). Although many studies have demonstrated correlations between eCAP-based and behaviourally derived maps, the literature indicates no significant improvement in speech understanding when map optimisation is based solely on eCAP measures (Smoorenburg et al., 2002).

On the other hand, eSRT is the widely used method for determining the USL. Holder et al. (2024) found that eSRTs showed a strong and consistent correlation with the USL across all three major manufacturers in adults. USLs were recommended to be set just below the eSRT: approximately 15 clinical units lower for Cochlear, 11 for Advanced Bionics, and nearly equivalent to eSRT for MED-EL limited. It suggests that eSRT provides a reliable and objective reference for establishing a safe USL, particularly when patient feedback is limited (Holder et al., 2024). Despite its utility,

eSRT cannot always be recorded, often due to postoperative stiffening of the middle ear or pre-existing middle ear pathology in the contralateral ear (Gabr et al., 2024).

Although eCAP and eSRT are most employed, eABR may be preferred in specific clinical situations, such as in patients with auditory neuropathy, when there is uncertainty about brainstem pathway integrity, or in cases of cochlear malformations where eCAP measurements are not feasible (Gabr et al., 2024). In patients with a malformed cochlea, eABR offers high sensitivity and accuracy in confirming the proper auditory signal transmission from the cochlea through the auditory nerve to the brainstem (Kim et al., 2008).

Variability in CI practice is evident in programming methods and mapping schedules, which differ considerably across centres. Moreover, programming a CI extends beyond establishing LSLs and USLs; additional parameters such as the strength of each pulse (amplitude), how long each pulse lasts (pulse width), how quickly pulses are delivered (stimulation rate), how many electrodes are active at once, the way those electrodes are linked, and their overall arrangement, also influence perception (Banda González et al., 2017). Alzhrani et al. (2024) study on intraoperative measurements, highlighted the lack of consensus regarding intraoperative measures, similarly persists in CI mapping procedures, where no standardised protocol exists in the literature. This absence of a uniform guideline leaves uncertainty among clinicians about which assessments are essential and which are not. Establishing a standardised protocol is essential for promoting greater consistency in clinical practice, providing more precise guidance for professionals, and contributing to the refinement of best-practice recommendations for CI mapping.

Morris (2022) surveyed audiologists working with CI in India to document the current mapping practices, the findings revealed that most clinicians relied primarily

on the manufacturer default setting, making modifications only in the relevant clinical circumstances. the study highlighted the routine use of electrode impedance checks and eCAP measurements and less frequent is of eSRT and eABR. Practices also showed significant variation from the recommendations of Cochlear Implant Group of India (2018), with most centres and clinicians following their own preferred approaches. Overall, the study highlighted a strong dependance on default setting across manufacturers, inconsistent use of objective measures, and lack of uniformity in CI mapping practices across India.

1.1 Need for the Study

The use of CI to support communication in individuals with hearing loss is steadily increasing worldwide. As a result, it has become essential for professionals in the hearing health care, including both experienced and newly trained, to understand the fundamentals of providing appropriate CI care. The rehabilitation journey, involves multiple stages, each of which is critical. The initial stage of candidacy evaluation, which includes comprehensive audiological assessments, medical examination, and counselling to determine suitability. This is followed by surgical implantation and subsequent mapping procedures to ensure sounds are comfortable and meaningful for the listener. Ongoing follow-up visits then play a vital role in facilitating adaptation, monitoring progress, and maximising long-term benefits from the implant.

Over the years, the candidacy criteria have expanded considerably; however, their evolution has differed across regions of the world (Van De Heyning et al., 2022) due to new research and technological advances (Warner-Czyz et al., 2022). Many countries have provided detailed criteria for candidacy for both children and adults (Warner-Czyz et al., 2022; Zeitler et al., 2024). National or regional authorities have formally approved some candidacy recommendations. In contrast, others are based on

manufacturer-issued guidelines or evidence-based practices adopted before formal approval or guideline updates to existing guidelines (Warner-Czyz et al., 2022).

Beyond candidacy assessment and outcome measurement, another critical aspect of CI and a major one with respect to speech perception is device programming, which becomes particularly complex with multichannel implants. Ideally, recipients need to possess the language and conceptual skills to provide accurate feedback on loudness and sound quality for accurate mapping of CI; however, very young prelingually deaf children are often unable to do so reliably (Hodges et al., 1997). While global guidelines continue to evolve, in India, the Cochlear Implant Group of India (CIGI), which serves as the leading professional body guiding CI practitioners nationwide, primarily address issues related to implant candidacy, with limited emphasis on areas such as device programming and follow-up care (Morris, 2022). As a result, there is no detailed protocol to guide audiologists in mapping, which contributes to variability and a lack of uniformity in practice. Morris (2022) does not set the best practices, rather given a snapshot of the current CI care currently delivered in India, hoping that these insights will guide future research and ultimately help improve outcomes for children and adult receiving CI.

Consensus statements and the expert's opinions have previously been generated in other CI-related areas, such as candidacy indications and hearing preservation surgery (Alzhrani et al., 2024). These findings highlight a strong need for practical, content-specific guideline for CI mapping in India. Currently CI programming practices vary considerably across centers, with significant difference exists in the fitting procedures, mapping parameter modifications and follow-up procedures. The absence of standardised guideline make the mapping process especially challenging for less experienced professional (Browning et al., 2020;

Vaerenberg et al., 2014b; Wathour et al., 2021). Establishing such a protocol would support consistency in clinical practices, enable data pooling across center, and facilitate large-scale research studies. The study aims to gather insights from the experts working in the field and integrate them into a unified framework. Rather than a rigid rule book, this guideline will serve as a flexible reference, providing audiologists with a structured foundation they can adapt and build upon in individual clinical contexts.

1.2 Aim of the Study

The aim of the study was to develop evidence-based and contextually relevant criteria and guidelines for CI switch-on and mapping to be used by audiologists in India.

1.3 Objectives of the Study

The objectives of the study were to-

1. review the current global and Indian practices related to CI mapping procedures, with the aim of identifying best practices and gaps relevant to the Indian context.
2. to document current approaches to CI mapping techniques used in clinical practice.
3. develop standardised guidelines for CI programming (mapping), resulting in a reference guide tailored for audiologists working with CI users in India.

Chapter II

Review of Literature

Advancements in CI technology and the expansion of candidacy criteria have increased the number and diversity of recipients, underscoring the need for more efficient and flexible clinical management strategies to accommodate busy clinics and varied patient preferences (Selvaratnam & Teagle, 2025). CI processors need to be carefully adjusted and personalised for each user to help them hear sounds as clearly and comfortably as possible. After the implant surgery, the speech processor is programmed by customising the processor settings. The device can deliver sound in a way that better suits the individual, helping them understand speech more easily and communicate more effectively in everyday listening situations.

Despite the importance, there are circumstances where there are no standardised protocols to allow a uniform practice across professionals (Browning et al., 2020). There is a body of literature pointing out the lack of this evidence in CI audiologists' practice procedures. To date, few studies have been published on this topic worldwide (Browning et al., 2020; Fielden & Kitterick, 2016; Rossi-Katz & Arehart, 2011; Siburt & Holmes, 2015; Vaerenberg et al., 2014b; Wathour et al., 2021). In the Indian context, Morris (2022) conducted an online survey to address the knowledge gap regarding these clinical practices and follow-up care. The survey focused more on the dependence of default-setting parameters on professionals and attempted to analyse common practices among audiologists across India. The Cochlear Implant Group of India (CIGI) is the professional organisation established to provide guidance professionals in CI related field across India. However. its recommendations are non-mandatory and primarily focuses on CI candidacy, with comparatively less importance on the device programming and follow-up care (Morris, 2022.; Vishwakarma & Mohandas, 2018)

Therefore, the literature review was conducted to identify current practices, recommendations, challenges, and variability in CI mapping procedures. Relevant articles, clinical practice guidelines, and manufacturers' recommendations were reviewed to obtain information related to CI programming practices. Electronics databases, including PubMed, Google Scholar, ScienceDirect and ResearchGate, were searched to identify the relevant literature. In addition, manual searches of reference lists from selected articles and clinical guidelines were performed to identify relevant references. A combination of keywords relevant to the topic was used, along with Boolean operators such as “AND,” “OR,” and “NOT,” to find related articles. The primary search terms included; “cochlear implant mapping,” “cochlear implant programming,” “switch-on procedures,” “objective measures in cochlear implants,” “eCAP,” “eSRT,” “electrode impedance telemetry,” “follow-up mapping,” “bilateral cochlear implant fitting,” “bimodal cochlear implant fitting,” “default cochlear implant parameter settings,”. Thus, this chapter reviews the literature related to CI mapping procedures under the following headings:

2.1 Readiness and timing of switch-on

2.2 Electrode impedance measurements and electrode status

2.3 Progressive maps and challenges during initial switch-on

2.4 Follow-up mapping practices

2.5 Determination of LSLs and USLs in CI mapping

2.6 CI map stability and optimization

2.7 Current practices and challenges in CI mapping

2.1 Readiness and Timing of Switch-On

The initial activation of a CI, commonly referred to as ‘switch-on’, requires careful pre-programming assessment to confirm that the recipient is clinically ready for

stimulation. Roux-Vaillard et al. (2020) established that the delay between surgery and switch-on is primarily intended to address post-operative concerns such as oedema, intracochlear inflammation, risk of infection, and potential displacement of the internal magnet. These physiological considerations necessitate a structured evaluation of the surgical wound site, including inspection for redness, swelling, tenderness and any signs of active infection prior to activation. Chen et al. (2015) further emphasised that initial activation should be guided by the post-operative healing status, the absence of surgical complications, and explicit clearance from the operating surgeon before proceeding. The American Academy of Audiology (AAA) clinical practice guidelines for CI, as documented by Messersmith et al. (2019), elaborated on the multidisciplinary nature of post-operative management and highlighted wound monitoring, medical follow-up and appropriate candidacy confirmation as pre-requisite for activation.

Alzhrani et al. (2024) reinforced the importance of intraoperative measurement as early indicators of potential post-operative issues requiring monitoring or clinical management. In the event that any abnormality is identified intraoperatively, it is the surgeon's responsibility to address it; however, post-operative challenges during switch-on fall under the clinical boundary of the audiologists (Vishwakarma & Mohandas, 2018). The CIGI guidelines outlined by Vishwakarma and Mohandas (2018) specifically emphasized reviewing imaging data, including pre-implant CT and MRI findings, to confirm inner ear anatomy and electrode placement. Sennaroğlu and Demir Bajin (2017) further documented the importance of reviewing pre-implant radiological reports, particularly in cases involving inner ear malformations, to appropriately guide switch-on decisions and mapping procedures.

Beyond wound healing and medical clearance, behavioural readiness is an equally important domain for confirming suitability for CI activation. Wolfe and Schafer

(2015) described how factors such as attention span, fatigue, illness and patient cooperation significantly influence the quality of the programming session, especially in pediatric CI recipients. These considerations are not limited to switch-on but apply throughout the entire CI mapping journey, as unreliable behavioural responses at any session can compromise the accuracy of the required stimulation levels. Similarly, the literature also discussed the need to adapt programming procedures to the individual recipient's condition, level of cooperation, and general clinical state (Browning et al., 2020; Vaerenberg et al., 2014b). Through the clinical practical guideline, Messersmith et al. (2019) also highlighted patient behavioural cooperation and overall clinical condition as core considerations in the CI mapping procedure, especially during the initial activation.

2.1.1 Intra-Operative Electrophysiological and Imaging Review

Reviewing intra-operative electrophysiological and imaging data is a critical step before proceeding with initial CI activation. Several authors, including Previous literature, also recommended intra-operative imaging, such as X-ray, to confirm the location and position of the electrode array within the cochlea (Bettman et al., 2003; Czerny et al., 1997; Lawson et al., 1998a; Marsh et al., 1993a; Shapiro & Bradham, 2012). Several authors noted that while intra-operative measurements can confirm electrode functionality, they are insufficient for verifying intra-cochlear placement, as electrode impedance values can still be obtained even when electrode contacts are positioned outside the cochlea (Busby et al., 2002; Goehring et al., 2013). Gordon et al. (2004), Stephan and Welzl-Müller (2000), and Wiley and Fowler (1997) collectively demonstrated that the presence of an intraoperative electrically evoked stapedial reflex (eSRT) serves as an indicator of an intact ascending and descending stapedial reflex arc pathway. Mason et al. (2001) showed that intra-operative eCAP findings correlate

significantly with early behavioural T levels and eABR findings, supporting the review of objective intra-operative measures as a foundational step before CI activation.

2.1.2 Timing of Initial CI Switch-On

The timing of initial CI activation has been a topic of considerable debate in the literature. Vaerenberg et al. (2014b), in their global survey of CI mapping practices, reported that the traditional recommendation for initial activation was approximately 10 to 30 days post-surgery, reflecting concerns about wound healing, magnet displacement, and electrode impedance variability. Marsella et al. (2014) also documented concerns about interference with wound healing and fluctuating electrode impedance values as a reason for the conventional waiting period. However, advances in surgical techniques, including shorter operating times, smaller incisions, and shorter hospital stays, have prompted growing interest in early and immediate activation (Coelho et al., 2023; Marsella et al., 2014; Roux-Vaillard et al., 2020).

Coelho et al (2023) argued that early switch-on is not only feasible but offers practical, real-world benefits for CI recipients and their families, including earlier auditory access and reduced anxiety about device function. Saoji et al. (2022) demonstrated that electrode impedance drop occurred more rapidly in the early activation group than in those activated later and reported that only a small percentage of recipients were unable to tolerate early activation. Alsabellha et al. (2014), Chen et al.(2015), and Wolfe et al. (2015) all concluded that early CI activation did not interfere with wound healing or fitting parameters, suggesting that it can be considered on an individual basis. Chen et al. (2015) found significant improvements in hearing following early activation, and Sun et al. (2019) reported better speech-perception outcomes in the first month post-surgery, although no significant difference between the early and delayed activation groups was observed at three months. Marsella et al. (2014) and

Roux-Vaillard et al. (2020) confirmed comparable long-term auditory performances across both approaches. Selvaratnam and Teagle (2025) and Sunwoo et al. (2021) further documented the emerging clinical shift towards next-day CI switch-on as an evolving practice. Nevertheless, there is no published literature on this topic in the Indian context.

2.2 Electrode Impedance Measurements and Electrode Status

Electrode Impedance measurement is a foundational step in every CI mapping session and provides essential information about the electrode-tissue interface, circuit integrity, and overall device function. Wathour et al. (2021) and Vaerenberg et al. (2014b) both reported that electrode impedance testing is routinely performed at the beginning of each mapping session, with repeat measurements recommended whenever abnormal patterns are observed. Henkin et al. (2006) demonstrated that electrode impedance values change across sessions, underscoring the necessity for consistent monitoring throughout the CI mapping process. Henkin et al. (2006) and Hughes et al. (2001) jointly documented that electrode impedance typically shows a rapid increase during the early post-activation period (immediately after switch-on), and subsequently decreases gradually before stabilising over time, in both pediatric and adult CI recipients. Brummer & Turner (1977) provided the physiological explanation for this decline, attributing it to the formation of a hydride layer at the electrode-tissue interface over time.

Dagkiran and Tanrisever Pehlivan (2026) described multiple factors influencing electrode impedance, including the electrode-tissue interface, the surrounding fluid environment, and the resistance of electrode contacts and lead wires. Wilk et al. (2016) highlighted the functional consequences of high electrode impedance, including saturation of the current source, reduced dynamic range, and increased energy consumption, leading to shortened battery life. Carlson et al. (2010) addressed the

clinical management of individual electrode circuit failures, noting that persistent circuit abnormalities may cause reduced sound perception, non-auditory stimulation, or represent early signs of progressive device malfunction, with electrode deactivation as the first line of management and reimplantation reserved for cases with three or more individual circuit failures. Cochlear Limited (2023) recommended modifying the map to bring out-of-compliance electrodes into compliance before considering deactivation. Vaerenberg et al. (2014b) identified abnormal electrode impedance patterns and confirmed extracochlear electrode positions as the most common reasons for electrode deactivation. Fielden and Kitterick (2016) and Wathour et al. (2021) both confirmed that troubleshooting procedures related to electrode impedance do not differ significantly between pediatric and adult CI recipients.

2.3 Progressive Maps and Challenges During Initial Switch-On

Progressive mapping, wherein stimulation levels are gradually increased across multiple sessions to allow the auditory system to acclimatise to the electrical stimulation, is not universally required for all CI recipients. Chinnici (2006) recommended that decisions to use progressive mapping are highly dependent on the fitting approach and the individual recipient's profile, including auditory-perception capacity and the ability to participate in programming sessions, particularly in the pediatric CI population. The Alexander Graham Bell Association (2014) recommended that the remapping schedule be individualised based on age and accessibility to regular follow-up services. Vaerenberg et al (2014b) reported that over 70% of their survey participants routinely recommended progressive maps regardless of age, reflecting broad international practice at the time.

Shapiro and Bradham (2012) identified several common challenges encountered during initial switch-on, including difficulty maintaining a comfortable environment for

pediatric recipients, difficulty obtaining reliable behavioural responses from young or uncooperative clients, and the occurrence of non-auditory stimulation (e.g., facial nerve stimulation) in cases involving an extracochlear electrode. Technical issues with software or connectivity may also arise during initial activation. Parental or caregiver anxiety regarding the procedure and expected outcome is widely documented as a challenge, and the importance of a multidisciplinary team involved to reduce this anxiety and improve understanding of the process is emphasised in the literature (Shapiro & Bradham, 2012).

2.4 Follow-Up Mapping Practices

Post-activation follow-up is a critical component of the CI rehabilitation pathway, and the frequency of follow-up sessions has been addressed in multiple studies and guidelines. Vaerenberg et al. (2014b) reported that global CI mapping practice typically involves monthly sessions initially, followed by quarterly visits, resulting in approximately seven follow-up sessions within the first-year post-activation. The CIGI guidelines (Vishwakarma & Mohandas, 2018) emphasised importance of consistent follow-up during the initial post-activation period rather than prescribing a rigid visit schedule. The AAA guidelines (Messersmith et al., 2019) provided an approximate follow-up schedule that can be tailored to individual recipient's conditions and accessibility constraints. Vaerenberg et al. (2014b) also noted that follow-up frequency may vary depending on individual recipient requirements and access to CI programming services.

Map stability is generally achieved through gradual adaptation during the initial months following activation. Brummer and Turner (1977) documented that USL value plateau at approximately one year post switch-on, reflecting acclimatisation to electrical stimulation and increasing loudness tolerance over time. Shapiro and Bradham (2012)

confirmed that programming parameters generally stabilise within the initial months following activation. Vaerenberg et al. (2014b) further suggested that an intensive schedule of consecutive mapping sessions in the early post-activation period can facilitate faster achievements of a stable map. Practical indicators of map stability include consistent aided thresholds, stable speech perception outcomes, adequate dynamic range, and minimal changes across consecutive sessions.

2.5 Determination of LSLs and USLs in CI Mapping

Determining LSLs and USLs is a central task in every CI mapping session, as these values define the dynamic range of stimulation delivered to the cochleae. The literature reports that LSLs and USLs undergo the most significant change across successive mapping sessions (Vaerenberg et al., 2014a; Vaerenberg et al., 2014b). Additionally, it is reported that the stimulation levels are primarily determined using behavioural methods, supplemented by objective measures, and that not all electrodes are measured. Most of the time, representative electrodes are measured, and the values are interpolated in the other electrodes (Shapiro & Bradham, 2012; Vaerenberg et al., 2014b). This practice was consistent across the survey by Morris (2022) and Browning et al. (2020).

2.5.1 Behavioural Methods and Loudness Scaling

Behavioural methods remain the primary approach for determining these levels. Holder et al. (2023) identified three major methods for determining USLs: Loudness scaling, eCAP and eSRT. Geers et al. (2003) cautioned that loudness ratings are highly variable among individuals with hearing impairment, limiting their reliability as a sole measure. For pediatric CI recipients, Shapiro and Bradham (2012) acknowledged the difficulty of obtaining reliable behavioural measures and recommended a supportive,

multidisciplinary environment during initial programming sessions to reduce parental anxiety and improve response reliability.

The electrical stimulation threshold refers to the lowest intensity of biphasic electrical pulses delivered through the CI electrodes that elicits a detectable auditory percept in the user. CI manufacturers differ in their definition, nomenclature, and measurement units for electrical stimulation threshold. The stimulation threshold should be established accurately to optimise access to soft sounds, and in most pediatric patients, it can be determined using conditioning and observation methods tailored to the child's developmental age. Age-appropriate behavioural assessment techniques, including Behavioural Observation Audiometry (BOA), Visual Reinforcement Audiometry (VRA), Conditioned Play Audiometry (CPA), and standard audiometric procedures for adults, may be employed for threshold determination (Banda González et al., 2017).

Accurate determination of USLs is crucial as they influence the top of the electrical dynamic range and ensure appropriate transmission of mid- to high-level auditory information (Holder et al., 2023). Consequently, excessive compression or expansion of the electrical dynamic range may adversely affect speech recognition performance and perceived sound quality (Holder et al., 2024). When USLs are set too low, the electrical dynamic range becomes compressed. Given the restricted electrical intensity resolution available to CI users, this may lead to reduced loudness discrimination across soft and loud sounds, poor speech recognition in noise, diminished sound quality, and impaired self-monitoring of vocal output. Excessively high USLs can expand the electrical dynamic range, potentially causing loudness discomfort, degraded sound quality, and poorer speech recognition (Holder et al., 2024).

2.5.2 Objective Measures eCAP and eSRT

Objective electrophysiological measures play a critical supportive role in CI programming, particularly in recipients who cannot reliably respond to behavioural assessments. Vaerenberg et al. (2014b) reported that eCAP measures are commonly used to derive LSL estimates, whereas eSRT responses are more often used to guide USL determination.

eCAP is known by different names depending on the manufacturer: in Cochlear Limited devices, it is Neural Response Telemetry (NRT), while in Advanced Bionics devices, it is Neural Response Imaging (NRI). Similarly, MED-EL uses the term Auditory Nerve Response Telemetry (ART). Despite these different names, all systems measure the same underlying neural response, helping audiologists estimate appropriate stimulation levels and optimise device programming, especially in patients who cannot provide reliable behavioural feedback.

Clinicians often rely on evoked potentials, particularly eCAP thresholds, as a preliminary guide for setting LSLs and USLs. However, these values are not regarded as fixed points; instead, they serve as an initial reference and are subsequently modified during live testing based on the patient's loudness perception (Allam & Eldegwi, 2019). Although many studies have demonstrated correlations between eCAP-based and behaviorally derived maps, the literature indicates no significant improvement in speech understanding when the map is based solely on eCAP measures (Smoorenburg et al., 2002).

Previous studies have investigated the relationship between CI outcomes and eCAP measures. In children who are unable to provide reliable behavioural responses, eCAP thresholds have been shown to correlate significantly with behavioural T-levels across basal, middle and apical electrodes. Furthermore, eCAP thresholds were not

found to be either equivalent to or higher than behvioural T-levels and fell within the programed dynamic range for approximately 90% of the electrodes evaluated (Sasidharan et al., 2025).

The systematic review by de Vos et al. (2018) highlighted an important limitation of eCAP measures, demonstrating that the overall correlation between eCAP thresholds and behavioural stimulation levels was only weak to moderate. These findings suggest that eCAP should be used as a supportive tool rather than as a standalone determinant of programming levels. Van Eijl et al. (2017) reported that eCAP thresholds are only limited predictors of behavioural stimulation levels, even when corrected using behavioural data. As eCAP measures reflect neural responses to isolated pulses rather than the temporal integration underlying loudness perception, they should be used as adjunctive rather than definitive measures for CI fitting.

In summary, eCAP thresholds have limited utility as standalone predictors of behavioural stimulation levels, even when corrected using behavioural data. This discrepancy arises because eCAP response reflects neural response to isolated pulses, whereas behavioural loudness perception depends on temporal integration of neural activity during high rate of stimulation. Therefore, individual differences in the effect of stimulation rate on loudness perception should be considered when using eCAP measures to support CI mapping. The following Table 2.1 represents clinical utility of eCAP measures in CI Mapping.

Table 2.1

Clinical utility of eCAP measures in cochlear implant mapping

Author(s) & Year	Population / Context & Comparison	Key Findings	Correlation (r)
Allam & Eldegwi (2019)	Children; mean age of 4.2 years; eCAP vs T-level & C-level	eCAP thresholds significantly differ from behavioural levels; they consistently fall within the dynamic range (T < eCAP < C). Significant positive correlation; eCAP thresholds generally higher than T-levels.	Not specified
Brown et al. (1994)	eCAP vs psychophysical thresholds (single pulses)	Strong correlation under controlled conditions (low-rate/single pulse)	0.89
Gordon et al. (2004)	Children; mean age of ~ 4.6 years; eCAP vs behavioral levels	High variability and weaker correlations across subjects	0.2–0.7
Smoorenburg et al. (2002)	Adults; mean age of 53.21 years; eCAP (35 Hz) vs behavioral T & C (250 Hz)	Reduced correlation due to a mismatch in stimulation rates	0.5–0.6
Zimmerling & Hochmair (2002)	Ineraid users; age not reported; eCAP vs thresholds	Strong correlation at the same rate; weak or no correlation at higher rates	0.89 (same), ~0.5 (high rate)

Table 2.1 (Continued)

Clinical utility of eCAP measures in cochlear implant mapping

Author(s) & Year	Population / Context & Comparison	Key Findings	Correlation (r)
McKay et al. (2005)	CI fitting; eCAP vs LSL & USL	Moderate correlation; eCAP cannot fully predict loudness levels	Moderate
Brown et al. (1994); Hughes et al. (2001)	CI users; eCAP + behavioural correction	Correlation improves when one electrode's behavioural data is used for calibration	0.8–0.9
Brown et al. (2000)	Adult CI users; mean age 59.8 years; eCAP and eABR thresholds compared with T and C levels	Strong correlation between eCAP thresholds and behavioural map levels	0.77 -0.83
Cullington, (2000)	CI recipients; age not specified; eCAP thresholds compared with psychophysical thresholds and comfort levels	Post-operative NRT thresholds showed significant correlations with behavioural threshold and comfort levels, but variability was too large for direct MAP setting. NRT thresholds were consistently audible to patients.	0.67 (threshold), 0.69 (comfort level)
Hughes et al. (2000)	Pediatric CI users; mean age of 6.7 ± 2.5 years; eCAP vs behavioural map levels	Strong correlation between eCAP and map levels . correlation improved when eCAP were corrected using behavioural data from one electrode	0.87 (T-levels), 0.89 (C-levels)

Table 2.1 (Continued)

Clinical utility of eCAP measures in cochlear implant mapping

Author(s) & Year	Population / Context & Comparison	Key Findings	Correlation (r)
Franck & Norton (2001)	Adult CI user; mean age of 52 years; eCAP vs psychophysical T and C levels	eCAP thresholds are highly correlated with psychophysical T levels; correlation with C levels were weaker and more variable	T-level: r = 0.76–0.77; C-level: weak/non-significant
Thai-Van et al. (2001)	Pediatric CI recipients; mean age at implantation = 4 years ; eCAP thresholds compared with behavioural T- and C-levels over 12 months	Correlation between NRT thresholds and behavioural levels improved over time. Strong correlations were observed at 12 months post-implantation across all tested electrodes, particularly in apical electrodes.	r = 0.69–0.97
Polak et al. (2005)	Adult CI users; mean age of 50 years; compared eCAP and eSRT thresholds with behavioural T and C levels	eSRT showed stronger correlations with C-levels than eCAP.	eCAP–C level: r = 0.76–0.85; eSRT–C level: r = 0.93–0.95

Note: eCAP - electrically evoked compound action potential, eSRT - electrically evoked stapedial reflex threshold, eABR- electrically evoked auditory brainstem response, CI - cochlear implant

On the other hand, an objective approach that could be useful for mapping is eSRT, a widely used method for determining the USL. eSRT is commonly used as a proxy to estimate the maximum comfortable level of electrical stimulation in CI users. It may be particularly useful for young children and those who cannot provide subjective sound-perception responses (Guo et al., 2021; Lorens, 2004; Palani et al., 2022; Walkowiak et al., 2011). eSRT can be measured postoperatively using an immittance meter in the implanted or nonimplanted ear to gauge the response to electrical stimulation through the implant. There is a strong association between CI programs developed using behavioral techniques and eSRT recording to assess C levels. Holder et al. (2024) reported a strong correlation between eSRT threshold and MCL, particularly for MED-EL devices, with eSRT thresholds often corresponding directly to the MCL. Walkowiak et al. (2011) also identified eSRT as a better predictor of USL than eCAP, supporting its preferred use for USL determination in clinical practice. Table 2.2 below presents the role of eSRT in the CI mapping procedure.

Table 2.2

Clinical utility of eSRT measures in cochlear implant mapping

Author(s) & Year	Population / Context & Comparison	Key Findings
Jerger et al. (1988); Wu et al. (2015)	CI users; eSRT vs C-level (comfort levels)	Significant relationship between eSRT and behavioral comfort levels (LSL &USL)
Bresnihan et al. (2001)	Pediatric CI users; eSRT-based vs behavioral maps	eSRT-based levels are lower than behavioral levels; improved wearing time and reduced discomfort
Lorens (2004); Raghunandhan et al. (2015)	CI users; eSRT vs behavioral mapping	Strong association between eSRT-based and behaviorally derived programs
Charroó et al. (2021)	CI users; eSRT vs USL using 1-, 4-, and 15-electrode stimulation	eSRT levels decrease with increasing electrode number; 15-electrode stimulation is closest to behavioral M-levels
Polak et al. (2005)	Adult CI users; mean age = 50 years ;eCAP and eSRT thresholds vs behavioural T- and C-levels	eSRT showed stronger correlations with C-levels than eCAP (eCAP–C level: r = 0.76–0.85; eSRT–C level: r = 0.93–0.95)
Sasidharan et al. (2025)	Adult CI recipients ; eSRT vs upper stimulation levels	Strong correlation (r = 0.80–0.86). USLs were on average 15.4 CL below eSRT for Cochlear (PW 25 μs), 13.4 CL below eSRT for Cochlear (PW 37 μs), 11.3 CU below eSRT for Advanced Bionics, and 0.1 qu above eSRT for MED-EL.

Note: eCAP - electrically evoked compound action potential, eSRT -electrically evoked stapedial reflex threshold, CI-cochlear implant

Holder et al. (2024) found that eSRTs showed a strong and consistent correlation with the USL across all three major manufacturers in adults. USLs were recommended to be set just below the eSRT: approximately 15 clinical units lower for Cochlear, 11 for Advanced Bionics, and nearly equivalent for MED-EL Limited. It suggests that eSRT provides a reliable and objective reference for establishing a safe USL, particularly when patient feedback is limited (Holder et al., 2024). Despite its utility, eSRT cannot always be recorded, often due to postoperative middle ear stiffening or pre-existing middle ear pathology in the contralateral ear (Gabr et al., 2024).

The programming of the CI is not only based on the parameters described above. It is widely known that the perception of sound is significantly influenced by other variables, including pulse amplitude, the duration of the phase or pulse-width, the stimulation rate, the number of electrodes stimulated at the same time, the electrode coupling mode, and the configuration of the electrodes, among others (Banda González et al., 2017). It is crucial for audiologists to understand the definitions and management of the different programming parameters of the CI that affect the intensity of the coded signal (Baudhuin et al., 2012).

Mason et al. (2001) demonstrated the clinical value of intraoperative eCAP findings as a preliminary reference for setting stimulation levels at switch-on and Goehring et al. (2013) cautioned that electrode impedance telemetry data should not be relied on independently, as electrode impedance values can be obtained even from extracochlear electrodes. Van der Beek et al. (2014) further emphasised that no single objective measure can reliably predict optimal behavioural stimulation levels, reinforcing the primacy of behavioural measures whenever achievable. Browning et al. (2020) and Vaerenberg et al. (2014b) both reported that the trend in clinical practice

reinforces reliance on behavioural responses as much as possible, with objective measures used as supportive tools.

2.6 CI Map Stability and Optimization

Currently, map stability is largely determined by the audiologist's interpretation of mapping parameters. While visual representation of map data is commonly recommended to monitor stabilisation, there is no universally accepted protocol or objective criterion specifying when a map can be considered stable (Wolfe & Schafer,2015). Map stability is generally determined through the audiologist's evaluation of whether programming parameters have ceased to show meaningful changes over time. However, this approach is inherently subjective, making it difficult to standardise and potentially resulting in variability across clinicians and centres. Once the map is considered stable, recipients are typically transitioned from intensive follow-up and rehabilitation to less frequent monitoring in accordance with the centre's clinical protocol.

Following the establishment of map stability, patients are typically reviewed on an annual basis for routine assessment and monitoring (Domville-Lewis et al., 2015). The duration and intensity of counselling and rehabilitation are closely linked to map stability, as recipients with unstable maps often require more frequent programming adjustments and intensive rehabilitation. Establishing map stability also enables rehabilitation efforts to focus on higher-level auditory goals, such as auditory training and, in bilateral implant users, the integration of input from both ears to maximise binaural benefit. However, there is currently no universally accepted definition of map stability in the literature. The development of a standardised definition would facilitate a reproducible and comparable approach to assessing map stability, thereby supporting

more consistent clinical decision-making across audiologists CI centres (Domville-Lewis et al., 2015).

2.7 Current Practices and Challenges in CI Mapping

Vaerenberg et al. (2014b) provided one of the earliest international overviews of CI fitting and follow-up practices. The survey was distributed to 47 CI centres across 17 countries, achieving a 100% response rate. In addition, 34 centres contributed detailed fitting data from five individual CI recipients each. The survey examined patient volume and projected growth, implant brands used, programming parameters, assessment methods for performance and programming, and outcome targets. The findings revealed considerable variability in clinical practices across centres. However, as most participating centres were based in Europe, the results may not fully represent global CI practices.

Vaerenberg et al. (2014b) also identified notable variations in clinical protocols across participating centers, with certain countries demonstrating practices that differed from the overall trends. For instance, Mumbai CI centres in India reported that follow-up appointments beyond the first postoperative year were generally scheduled only upon patient request. In contrast, most other centres routinely conducted at least annual follow-up evaluations after the first year. This finding is particularly relevant in the Indian context, as it highlights differences in long-term follow-up practices and underscores the variability in CI service delivery across centres.

Similar to Vaerenberg et al. (2014b), Jeyaraman (2013) conducted a survey examining general CI practices and habilitation services in India. The survey was distributed to 35 CI centres, with a response rate of 63%. As the survey primarily focused on habilitation services, most responses focused on practices for pediatric CI recipients. The findings revealed considerable variability in habilitation recommendations, with

approximately half of the centers recommending maps extending beyond one year, while the remining centers advised a one-year duration of habilitation services.

Prior to the availability of the governmental support schemes, CI in India required substantial out-of-pocket expenditure for both the device and long-term follow-up care. As a result, cost represented a major obstacle to treatment access, potentially limiting the acceptance and uptake of CI. This financial challenge may partly explain the relatively slow growth of CI in India following its initial introduction (Jeyaraman, 2013). Another contributing factor was the presence of social barriers, as many communities were initially reluctant to adopt this relatively new technology (Sampath Kumar & Kameswaran, 2018). However, survey findings reported by Vaerenberg et al. (2014b) and Jeyaraman (2013) suggest that these recommendations have not been consistently adopted in routine clinical practice.

Morris (2022) extended previous survey-based research by specifically examining CI clinical protocols within India, using a modified version of questionnaires from earlier international (Vaerenberg et al., 2014b) and U.S.-based (Browning et al., 2020) studies. The survey included 22 CI audiologists across diverse clinical settings in India, providing insight into real-world programming, follow-up, and rehabilitation practices. The findings highlighted significant variability in clinical protocols, particularly in mapping procedures, the use of objective measures, and follow-up strategies. Although most clinicians showed a strong preference for default manufacturer settings, there was inconsistency in the use of objective assessments such as eCAP, eSRT, and eABR, with reliance often placed on subjective feedback.

Additionally, the study revealed that bimodal fitting is widely recommended, especially in pediatric populations, and speech therapy remains a primary rehabilitation strategy, though the use of computerised auditory training is limited. Financial

considerations, including substantial reliance on government-funded programs, also play a major role in clinical decision-making in India. Overall, Morris (2022) reinforces the earlier observation of a lack of standardisation in CI practices, emphasising that clinical decisions are often individualised and influenced by resource availability, clinician experience, and patient-specific factors rather than uniform evidence-based protocols.

Although CI programming is fundamental to successful device outcomes, a lack of consensus exists among audiologists regarding programming strategies and the procedure used to establish LSLs and USLs (Vaerenberg et al., 2014b). At present, CI fitting is primarily guided by expert clinical judgement, whereby audiologists assess whether a recipient is achieving the anticipated auditory performance and modify map parameters when necessary to optimise outcome.

Considerable variability exists across CI centres with respect to fitting protocol, follow-up schedules, and programming methodologies. In many cases, the effectiveness of CI mapping is evaluated primarily through patient feedback, as there is no universally accepted set of quantitative measures or standardised targets to objectively assess the auditory status of CI. Consequently, modifications to the mapping parameters are often guided by a trial-and-error approach rather than by standardised evidence-based criteria (Vaerenberg et al., 2014a). The findings highlighted that well-defined outcome targets facilitate a structured, objective approach to evaluating CI mapping. Such targets support evidence-based clinical practice by enabling the monitoring and auditing of treatment outcomes. Moreover, they provide a clear framework for defining an optimised map, thereby enhancing consistency and standardisation across clinicians and CI (Vaerenberg et al., 2014a).

With respect to postoperative care related to CI programming and rehabilitation for both pediatric and adult populations, the Cochlear Implant Group of India (CIGI)

recommends obtaining an aided audiogram to confirm appropriate mapping and implementing weekly habilitation/rehabilitation sessions. For adults, this assessment should also include speech perception testing.

The group further recommends the development of standardised tests for speech perception, for all regional languages, highlighting the current lack of such tools (The Cochlear Implant Group of India, 2018). However, beyond these points, the recommendations remain limited. They do not provide detailed guidance on CI mapping procedures, frequency of follow-up adjustments, or specific audiological methods to be used during follow-up sessions. This lack of detailed direction leaves a gap in the clinical application and standardisation of CI fitting and follow-up practices.

Additionally, there is a lack of scientific evidence evaluating the impact of parameter modifications such as Input Dynamic Range, Volume sensitivity, and other advanced settings. As a result, the clinical relevance of these adjustments remains largely speculative and is often based on clinician experience rather than established evidence.

To summarise, the foregoing review of literature demonstrates that CI mapping is a complex, multi-domain clinical process that requires individualised decision-making within a structured framework. Key themes emerging from the literature include the importance of pre-activation readiness assessment (Roux-Vaillard et al., 2020; Chen et al., 2015; Messersmith et al., 2019), the evolving evidence supporting earlier activation timelines (Coelho et al., 2023; Saoji et al., 2022; Marsella et al., 2014), the centrality of electrode impedance monitoring in every mapping session (Wathour et al., 2021; Henkin et al., 2006; Wilk et al., 2016), the primacy of behavioural methods for stimulation level determination supplemented by objective measures (de Vos et al., 2018; Holder et al., 2024; Walkowiak et al., 2011), the conservative approach to default parameter modification (Morris, 2022; Wathour et al., 2021; Vaerenberg et al., 2014b), the need for

standardised bimodal and bilateral fitting practices (Litovsky et al., 2006; Browning et al., 2020; Fielden & Kitterick, 2016), and the imperative for improved clinical consistency within and across centres (Vaerenberg et al., 2014b; Messersmith et al., 2019). Collectively, this body of literature provides the empirical foundation for developing and validating a comprehensive, consensus-based CI mapping protocol for the Indian clinical context. The current clinical practice trend is even focusing on reducing the number of clinical visits by combining procedures that can be done in a single visit (Selvaratnam & Teagle, 2025). This has to be executed in a way that enhances the user's choice and improves clinical capacity to support growing CI utilisation (Selvaratnam & Teagle, 2025). Table 2.3 represents the summary of this chapter.

Table 2.3

Summary table of the literature review

Topic	Key Findings / Conclusions	Key References
Readiness for Initial Switch-On (Surgical site, medical clearance, behavioural readiness, intraoperative review)	Switch-on requires wound healing confirmation, absence of infection, and explicit surgeon clearance. Behavioural factors (attention, cooperation, fatigue) critically affect response reliability. Intraoperative imaging (X-ray) and electrophysiology (eCAP, eSRT,) must be reviewed before activation. Pre-implant CT/MRI review is essential, especially for inner ear malformations.	Roux-Vaillard et al. (2020); Chen et al. (2015); Messersmith et al. (2019); Vishwakarma & Mohandas (2018); Sennaroğlu & Demir Bajin (2017); Alzhrani et al. (2024); Mason et al. (2001); Wolfe & Schafer (2015)
Timing of Initial CI Switch-On (Traditional vs. early/immediate activation)	Traditional recommendation: 10–30 days post-surgery (wound healing, electrode impedance concerns). Evidence supports early switch-on as safe and feasible, with benefits of earlier auditory access. Electrode impedance drops faster in early activation groups. No significant long-term auditory performance difference between early and delayed activation groups. Next-day activation is an emerging practice.	Vaerenberg et al. (2014b); Coelho et al. (2023); Marsella et al. (2014); Saoji et al. (2022); Chen et al. (2015); Wolf-Magele et al. (2015); Selvaratnam & Teagle (2025); Sunwoo et al. (2021)

Table 2.3 (Continued)

Summary table of the literature review

Topic	Key Findings / Conclusions	Key References
Electrode Impedance Measurement (Electrode-tissue interface, abnormal patterns, deactivation)	Electrode impedance testing is mandatory at every session. Values rise rapidly post-switch-on, then gradually decline due to hydride layer formation. High electrode impedance reduces dynamic range and battery life. Persistent circuit failures may indicate device malfunction; electrode deactivation is first-line management; reimplantation is reserved for 3+ individual circuit failures. The troubleshooting approach does not differ significantly between paediatric and adult recipients.	Wathour et al. (2021); Vaerenberg et al. (2014b); Henkin et al. (2006); Hughes et al. (2001); Brummer & Turner (1977); Wilk et al. (2016); Carlson et al. (2010); Fielden & Kitterick (2016)
Determining LSL & USL (Behavioural methods, objective measures, manufacturer differences)	LSL/USL determination is the central mapping task with the most change across sessions. Behavioural methods (loudness scaling) are primary; levels are often set on a subset of electrodes (as few as 3) and interpolated. eCAP used for LSL estimation but shows only moderate correlation with behavioural levels. eSRT is a better predictor of USL. Manufacturer-specific approaches differ: Cochlear Ltd (separate LSL), MED-EL (THR locked at 8% MCL), Advanced Bionics (M levels from eCAP + offset).	Vaerenberg et al. (2014b); de Vos et al. (2018); Holder et al. (2023, 2024); Walkowiak et al. (2011); Shapiro & Bradham (2012); Geers et al. (2003); Van der Beek et al. (2014); Mason et al. (2001)

Table 2.3 (Continued)

Summary table of the literature review

Topic	Key Findings / Conclusions	Key References
Default Programming Parameters (Cochlear Ltd, MED-EL, Advanced Bionics)	Default settings (speech coding strategy, stimulation mode, loudness growth) should not be routinely altered -modified in only ~5–8% of cases globally. Cochlear Ltd: monopolar stimulation preferred; pulse width/rate adjusted for specific clinical needs; SCAN/SCAN-2 for paediatric, combined noise reduction + directional for adults. MED-EL: AGC and MapLaw adjusted when indicated; adaptive beamforming most effective. Advanced Bionics: IDR expanded for experienced users; UltraZoom + ClearVoice improve speech in noise.	Wathour et al. (2021); Morris (2022); Browning et al. (2020); Vaerenberg et al. (2014b); Shapiro & Bradham (2012); Gifford et al. (2011); Honeder et al. (2018); Mosnier et al. (2017)
Progressive Maps & Switch-On Challenges (Acclimatisation, paediatric challenges, troubleshooting)	Progressive mapping is not universal; it depends on the individual profile and the fitting approach. Over 70% of clinicians globally used progressive maps routinely at the time of the survey. Common challenges: unreliable paediatric behavioural responses, non-auditory/facial nerve stimulation, parental anxiety, and software/connectivity issues.	Chinnici (2006); Alexander Graham Bell Association (2014); Vaerenberg et al. (2014b); Shapiro & Bradham (2012)

Table 2.3 (Continued)

Summary table of the literature review

Topic	Key Findings / Conclusions	Key References
Bilateral & Bimodal CI Mapping (Interaural balancing, bimodal fitting protocols)	Bilateral CI: each ear mapped independently, then loudness balanced across devices; proper balancing improves binaural hearing and spatial perception. Bimodal: CI and hearing aid adjusted together, relying on clinical experience due to absence of a universal protocol. Significant inconsistencies in bimodal fitting practices documented.	Litovsky et al. (2006); Tyler et al. (2007); Messersmith et al. (2019); Browning et al. (2020); Fielden & Kitterick (2016); Siburt & Holmes (2015); Dorman et al. (2014)
Follow-Up Schedule & Map Stability (Session frequency, stability indicators)	Typical follow-up: monthly initially, then quarterly (~7 sessions in year 1). Consistent follow-up in the early post-activation period is more important than a rigid schedule. USL values plateau at approximately 1 year post switch-on. Intensive early mapping facilitates faster map stability. Stability indicators: consistent aided thresholds, stable speech perception, adequate dynamic range, and minimal changes across consecutive sessions.	Vaerenberg et al. (2014); Vishwakarma & Mohandas (2018); Messersmith et al. (2019); Brummer & Turner (1977); Vargas et al. (2012)

Note: LSL- lower stimulation level, USL- upper stimulation level, eCAP - electrically evoked compound action potential, eSRT - electrically evoked stapedial reflex threshold, CI- cochlear implant

Chapter III

Methods

The study used a survey method, in which the opinions and insights of professionals working on CI-related aspects were gathered and analysed qualitatively to reach the consensus statements. The study was conducted to generate consensus statements based on responses received from the experts across the country. Participants were recruited using voluntary response sampling.

3.1 Participants

The study's sample size was determined using the data saturation method, unlike quantitative research, where the focus is on numbers and statistics. Data saturation is said to be reached when additional responses no longer provide any new information or insights (Ahmed, 2025). One of the strengths of qualitative research is its flexibility in methodology as the study progresses (Denzin & Lincoln, 2011). This adaptability helps reach consensus on topics where predefined agreements are lacking. Determining data saturation depends on the research design, the nature of the research questions, and the richness of the data, and it plays a pivotal role in concluding data collection in similar studies (Hennink & Kaiser, 2022; Vasileiou et al., 2018). For the open-ended prompts, the frequency of responses was analyzed, and data collection was terminated after responses were received from 20 participants.

The study included 20 participants who were currently practicing in various settings across India. All the participants were enrolled through an email containing a link to the Google Forms questionnaire. Periodic reminders were sent consistently to encourage participants to complete the questionnaire. The demographic details of the participants are given in Table 3.1.

Table 3.1

Demographic and experience-related details of the study participants

Participant No.	Age (Years)	Gender	Professional Experience (Years)	Current Professional Role	Region	Cochlear	MED-EL	Advanced Bionics
1	32	Female	5–10 years	Senior Audiologist	Southern India	75–100	>100	1–25
2	49	Male	>10 years	Clinician and Trainer	Eastern India (Kolkata)	>100	>100	1–25
3	49	Female	>10 years	Clinician and Trainer	Kolkata, West Bengal	>100	51–75	1–25
4	27	Male	5–10 years	PhD Scholar	Chennai	1–25	75–100	–
5	31	Female	5-10 years	Clinician	Kerala	1–25	75-100	–
6	39	Female	>10 years	Clinician	Delhi	>100	75–100	51–75
7	34	Female	>10 years	Clinician	Kerala	75–100	51–75	75–100
8	49	Female	>10 years	Clinician and Trainer	West India (Surat, Gujarat)	75–100	75–100	75–100

Table 3.1 (Continued)

Demographic and experience-related details of the study participants

Participant No.	Age	Gender	Professional Experience (Years)	Current Professional Role	Region	Cochlear	MED-EL	AB
9	54	Male	>10 years	Clinician, Researcher, Trainer	Kerala	>100	>100	>100
10	30	Female	5-10 years	Clinician	Kerala	75–100	75–100	75–100
11	31	Female	5-10 years	Clinical Specialist	Chennai	–	75–100	–
12	53	Male	>10 years	Clinician, Academic and Trainer	Tamil Nadu	>100	–	75–100
13	54	Female	>10 years	Academic and Clinical Role	West	>100	–	1–25
14	48	Female	>10 years	Associate Professor	Chennai	>100	>100	>100
15	33	Male	5–10 years	Clinical Specialist	Tamil Nadu	26–50	>100	26–50

Table 3.1 (Continued)

Demographic and experience-related details of the study participants

Participant No.	Age	Gender	Professional Experience (Years)	Current Professional Role	Region	Cochlear	MED-EL	AB
16	33	Female	5–10 years	Academic and Clinical Role	Bengaluru	51–75	75-100	1–25
17	38	Male	5–10 years	Clinical Audiologist	East	1–25	>100	1–25
18	42	Female	>10 years	Clinician	Mumbai	75–100	1–25	26–50
19	36	Female	>10 years	Clinician	Maharashtra	75-100	–	1–25
20	33	Male	>10 years	Clinician and Researcher	Western (Pune)	>100	>100	75-100

Note: AB- Advanced Bionics

3.1.1 Inclusion Criteria

- Qualified audiologists with a minimum of a Bachelor's degree in Audiology or Speech and Hearing (e.g., BASLP) or Master's degree (e.g., MASLP, M.Sc. Audiology) or PhD scholars in the field of Audiology.
- Audiologists currently practising in India in a clinical, academic, or hospital-based setup, with documented experience of at least 75-100 CI cases for the specific brand about which they are willing to provide information.
- Actively involved in CI services with at least 5 years of professional experience.

3.1.2 Exclusion Criteria

- Audiologists not involved in CI services.
- Students or interns without independent clinical responsibilities.
- Individuals not currently practising in India.

3.2 Procedure

The study's methodology adhered to the institutional review board's ethical norms (SH/IRB/M.4/AUD.24/2025-26). The participants' informed consent was obtained before accessing the main question sections.

3.2 Step 1: Literature Review

A literature review of peer-reviewed journal articles, manufacturer recommendations, and professional association guidelines related to CI switch-on, mapping, and follow-up was conducted. The review aimed to summarise current practices, commonly reported challenges, the objective and behavioural measures being used and areas where clear guidance is lacking. Findings from the review were used to shape the questions and inform the questionnaire content to generate responses.

3.2 Step 2: Questionnaire Generation

The literature review helped to build a questionnaire in a way that will tap the major aspects of the CI mapping procedures currently practised by the audiologists in India. The previous literature in this field has developed questionnaires specifically tailored to individual study objectives, indicating that no standardised questionnaire was available to directly adapt for the current study to address CI mapping procedures. Therefore, information from earlier studies and several question formats (Baudhuin et al., 2012; Morris, 2022; Selvaratnam & Teagle, 2025; Vaerenberg et al., 2014b) were included in the current questionnaire to address the CI mapping procedure as fully as possible.

The questionnaire was validated by four experts in the field (along with the authors) to ensure that the prompts were appropriate for participants and enabled them to describe practices, rationales, and challenges in their own words. The panel selected for the proofreading included audiologists from the institute, whose experience varied across the major manufacturers (Cochlear Limited, MED-EL, and Advanced Bionics). The expert's details are provided in Table 3.2.

Table 3.2

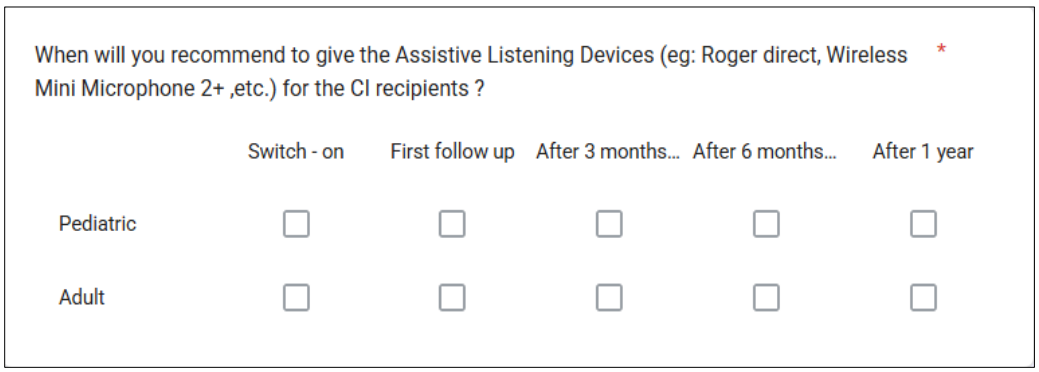
Details of experts and their role in the content validation of the questionnaire

Expert	Designation	Years of experience	Suggestions/ corrections provided
1	Professor of Audiology	>30	Added additional response options and areas missed to address
2	Clinical Audiologist	16	Added additional response options and areas missed to address
3	Assistant Professor in Audiology	16	Guided with respect to overall structure of the questionnaire
4	Associate Professor in Audiology	18	Co-Author

The panel suggested to provide options for possible questions, frame work for open ended questions to get homogenous responses (eg: A map is said to be stable if the USL not going beyond '___' levels from the previous map USL level). An example of a question in the form of a checkbox grid to select for the pediatric and adult populations separately, as given in Figure 3.1.

Figure 3.1

Example of a question given in a checkbox grid



The panel also suggested additional response options for several questions and identified areas that had been overlooked. These suggested changes were incorporated and subsequently reviewed for verification.

The questionnaire consists of three sections: the first covers participants' demographic details, and the second includes general questions on key areas, such as switch-on and follow-up mapping procedures. This section covers general procedures for CI mapping. The questionnaire began by addressing the switch-on procedure, the details to be observed before connecting the device for switch-on, and the pre-switch-on verification process for both pediatric and adult populations. The initial activation timing, in days, was also included as a question to assess trends in the pediatric and adult populations. Recommendations on electrode impedance measurement, electrode deactivation criteria, troubleshooting approaches for concerning electrode impedance patterns, use of progressive maps, loudness scaling methods, follow-up schedules,

mapping strategies for bilateral and bimodal CI users, determining map stability, and the use of assistive listening devices (ALDs) were also included.

The following sections were dedicated to manufacturer-specific information, where participants could select and provide information for as many CI manufacturers as they had clinical experience with, allowing them to share separate details for each manufacturer. Participants were asked to indicate the CI manufacturers with which they had experience in mapping. Based on their selection, they were directed to the relevant section for each company. The questionnaire included the three major manufacturers: Cochlear Limited, MED-EL, and Advanced Bionics. This section investigated practices related to the setting of LSLs and USLs, the incorporation of behavioural and objective measures, and modifications to the default programming parameters in each manufacturer's mapping software. It also addressed the pre-processing strategies recommended for both the pediatric and adult CI recipients. The final questionnaire is enclosed in the Appendix.

Participants were allowed to share information about as many manufacturers as they had worked with, which helped to ensure the questions they received were specific and relevant to their experience. Participants were encouraged to share as many items as they felt were important, including overlapping ideas, since repeated responses helped to show areas of common agreement. Items mentioned by fewer than 3 participants or that did not fit into the category were considered for removal, with all decisions being recorded for transparency.

The questionnaire was distributed primarily via Google Forms and collected from a panel of experts who volunteered to participate in the study. Overall, the questionnaire included both open-ended questions to elicit detailed expert opinions and multiple response questions to capture applicable responses, making the process less demanding.

3.2 Step 3: Panel Selection

Participants were identified through professional associations, published research, CI centres, and established professional networks, mainly from the Cochlear Implant Group of India (CIGI) website**.** The form was sent to more than 250 experts to invite them to participate in the study. It was aimed at including participants representing diverse clinical settings and geographic regions across India. An invitation was sent via email, outlining the study's purpose, expectations of participants, and the estimated time commitment.

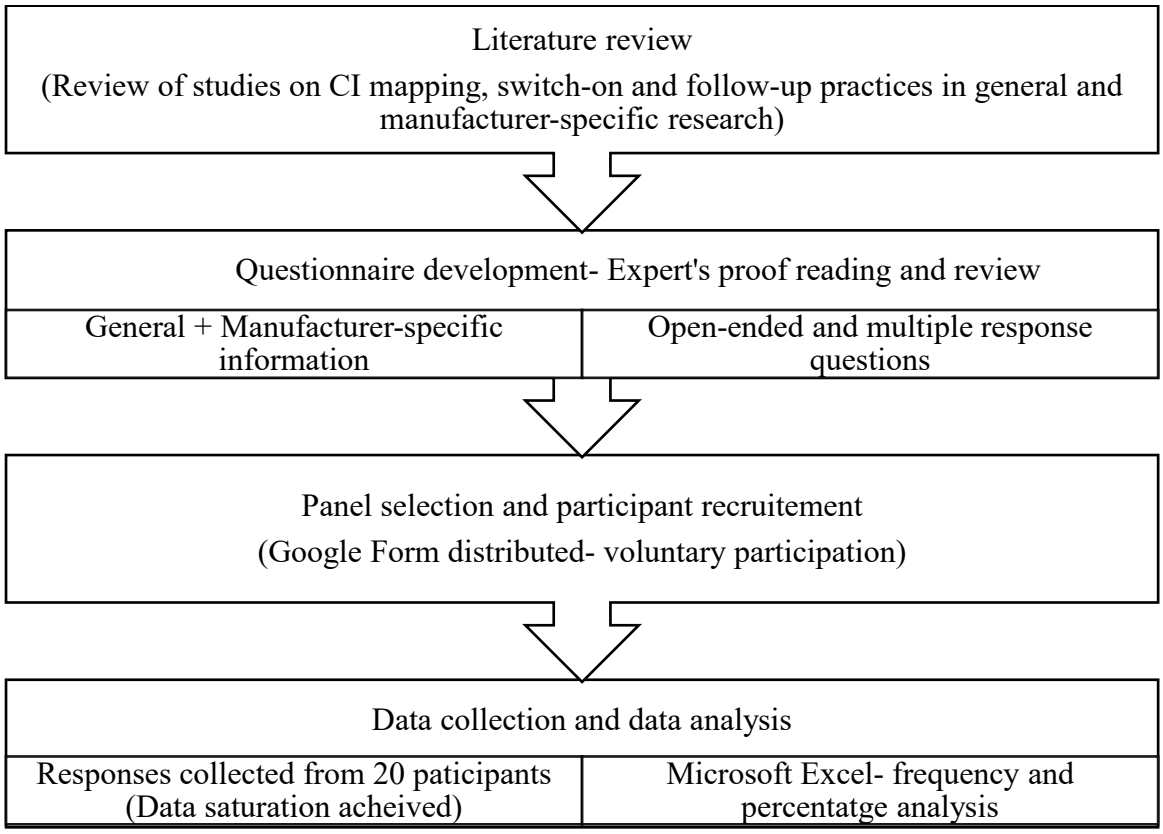
Instructions for the participants were given in the beginning of the questionnaire, wherein the aim and objectives of the study were highlighted. Participants were encouraged to share their opinions honestly and openly, as there were no "right" or "wrong" answers, and their real clinical experiences were considered valuable for the study. Instructions for completing the questionnaire were provided, outlining the overall structure of the Google Form: it began with demographic details, followed by general questions and manufacturer-specific information.

Instructions for completing the questionnaire were provided, outlining the overall structure of the Google Form: it began with demographic details, followed by general questions and manufacturer-specific information. Participants could provide responses for more than one manufacturer based on their experience. Throughout the questionnaire, instructions for filling each question were provided with each item, such as for multiple-choice questions, instructions such as "select all that apply" were given. In a similar way, for open-ended questions, instructions such as "Briefly explain in 2–3 sentences" were provided before each item. Before submitting the response, participants were required to cross-verify the section by selecting "I have completed all relevant manufacturer's sections" to prevent missing information.

Those who consented to participate in the study were encouraged to freely describe the procedures and parameters they follow in CI mapping, as well as those they believe should be included in guidelines for an individual new to CI mapping. For the majority of questions, to facilitate comprehensive responses, prompts were provided; while the options for several questions covered commonly reported responses, others included additional perspectives or details from the participant's point of view. This was addressed by adding the "Other" option to specify any information not listed, so it wouldn't be missed. The form was user-friendly, allowing participants to leave and return at their convenience and resume from where they left off. The overall study methodology is represented in Figure 3.2.

Figure 3.2

Methodology flow chart



3.3 Analysis

The collected data were analysed using Microsoft Excel, in which the frequency of responses was analysed separately for each section and each question. Responses to the open-ended questions were analysed individually to identify common themes and areas of agreement among participants. The answers to multiple-choice questions were analysed by calculating the percentage of responses for each option, while the additional responses from participants were also taken into consideration and are presented under the “Other” category in the responses.

Chapter IV

Results

The present study gathered and analysed professionals' opinions on CI mapping procedures regarding general aspects and manufacturer-specific information across different regions of India. An open-ended questionnaire was administered, and the professionals' responses were analysed qualitatively to derive the consensus statements.

4.1 Generation of Questionnaire and Content Validation

The first phase of the study was the review of the literature, which addressed current practice trends in the CI mapping procedure. The review assessed how the practices varied across manufacturers and the general trend observed. Based on that, the author and the core team prepared the questionnaire to address the CI mapping procedures followed by professionals. The questionnaire began with participants' demographic details, focusing on years of professional experience, qualifications, current working status, region of practice, and the number of CI cases each participant had handled across manufacturers.

The initial section of the questionnaire was dedicated to the general CI mapping procedures, including activation timing, pre-switch-on verification process, electrode impedance measurement, electrode deactivation criteria, troubleshooting approaches, use of progressive maps, loudness scaling methods, follow-up schedules, mapping strategies for bilateral and bimodal CI users, determining map stability and the use of assistive listening devices (ALDs).

The following sections focused on manufacturer-specific information, where participants could select and provide as many CI manufacturers as they had clinical experience with, allowing them to share separate details for each manufacturer. The questionnaire included the three major manufacturers: Cochlear Limited, MED-EL, and

Advanced Bionics. This section investigated practices related to the setting of LSLs and USLs, the incorporation of behavioural and objective measures, and modifications to the default programming parameters in each manufacturer's mapping software. It also addressed the preprocessing strategies recommended for both the pediatric and adult populations.

Overall, the questionnaire included both open-ended questions to elicit detailed expert opinions and multiple-response questions to capture all applicable responses, making the process less tedious. Prior to administration, the questions were reviewed and content validated by five professionals, including the authors and experts currently working in the field of CIs, to ensure clarity and relevance.

4.2 Questionnaire Responses

A total of 20 participants with varied clinical experience, ranging from 5 to 24 years, participated in the study. All participants had experience handling at least 75–100 CI cases with a single manufacturer. The distribution of participants across India reflected considerable diversity, including South, North, East, and West India, as well as metropolitan cities such as Chennai, Bengaluru, Delhi, Mumbai, Kolkata, and Pune, indicating broad geographical representation and highlighting that professionals from across the country contributed to the study.

The questionnaire items and a summary of responses, presented either as percentages representing response frequency or as consensus statements, are provided below under specific headings. Items mentioned by fewer than three participants or those that did not fit the category were considered for removal. Overlapping or duplicate ideas were merged, and repeated suggestions were rephrased into concise statements.

4.2.1 General Questions: Switch-On and Follow-Up Mapping

All 20 participants provided their insights and experience-based responses in this section. Since responses were obtained from 20 participants, each individual response carried a weight of 5% in this section.

Clinical Criteria for Confirming Readiness for Switch-On. Before connecting the implant to the programming software during the switch-on session, participants emphasised the importance of confirming the recipient's readiness for activation. All participants (100%) reported examining the surgical site for redness, swelling, or signs of infection and ensuring adequate wound healing. Most participants (95%) also considered medical clearance or surgeon approval essential prior to switch-on. In addition, clinicians reported reviewing relevant clinical information, including intraoperative electrode impedance measures (reported by 70%), intraoperative eCAP or stapedial reflex findings (reported by 65%), imaging reports confirming electrode placement (as per 65% of participants), and pre-implant CT/MRI findings (reported by 65%) before proceeding with activation. Additionally, 15% of participants recommended considering the child's general health status, including the presence of fever or illness, as well as the child's behavioural state, when determining readiness for switch-on.

Switch-On Procedures. On average, the majority (15 participants;75%) agreed that switch-on should be performed within 10-30 days following CI. A smaller proportion (3 participants;15%) recommended switch-on within 10 days, while 2 participants (10%) supported next-day/ immediate activation. For the adult population, most participants (13 participants; 65%) preferred switch-on within 10-30 days post-surgery. Five participants (25%) recommended activation within 10 days, whereas two participants (10%) agreed with the next day/immediate switch-on.

Electrode impedance Measurement. All participants start with electrode impedance measurement and following that an electrode may be considered for deactivation if in cases of persistently high electrode impedance values (e.g., open or short circuit electrodes) (as per 60%), when an extracochlear electrode position is identified (reported by 35%), when software recommendations or default system alerts indicate poor electrode function (reported by 35%), based on objective measures (e.g., eCAP, eSRT) also showing abnormal stimulation levels compared to neighboring electrodes (as per 15% of the participants).

Similarly, the majority of participants recommended rerunning the electrode impedance measurement when abnormal or concerning values are observed (70%), followed by rechecking the magnet strength to ensure appropriate coil retention and communication (30%). The presence of upper respiratory tract infection (URTI), ear pain, or other medical concerns should also be considered while interpreting abnormal electrode impedance values (reported by 20%). In addition, electrode conditioning may be performed as part of the troubleshooting process when electrode impedance values appear abnormal (as per 15%).

Furthermore, 70% of participants reported that there is no difference in troubleshooting steps concerning electrode impedance patterns between adults and children. Overall, all participants (100%) agreed that electrode impedance should be measured at every follow-up mapping session after the initial stabilisation period.

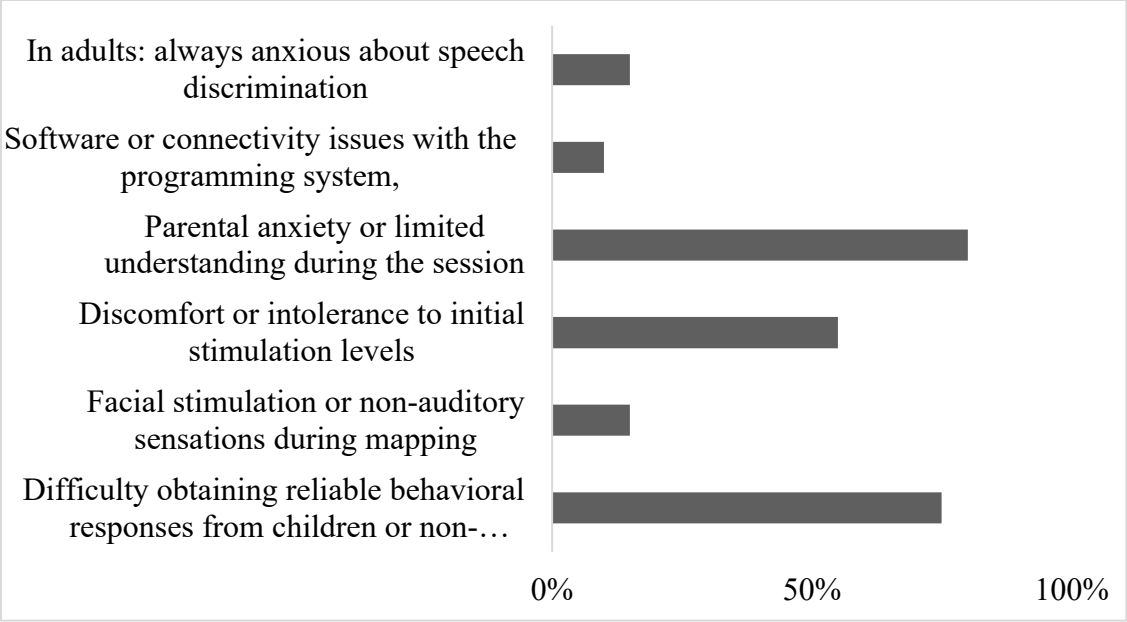
Progressive Map during Initial Switch-On. The decision regarding progressive maps showed partial agreement among participants, with 50% supporting their use during the switch-on session. Their use may vary between children and adults and should be determined based on individual patient factors, including age, cochlear anatomy, clinical

condition, listening responses, and access to regular follow-up services. Therefore, progressive maps may not be routinely applicable in all cases.

Challenges During Initial Switch-On. Frequently encountered challenges included parental anxiety or limited understanding of the procedure during the session (reported by 80%), difficulty obtaining reliable behavioural responses from children and non-cooperative clients (reported by 75%), and intolerance to initial electrical stimulation levels (reported by 55%). A few participants (15%) also reported facial stimulation or other non-auditory stimulation during mapping, along with anxiety regarding speech discrimination outcomes in adult CI recipients (as per 15%). These results are depicted in Figure 4.1.

Figure 4.1

Bar graph showing the percentage of challenges encountered during the initial switch-on.



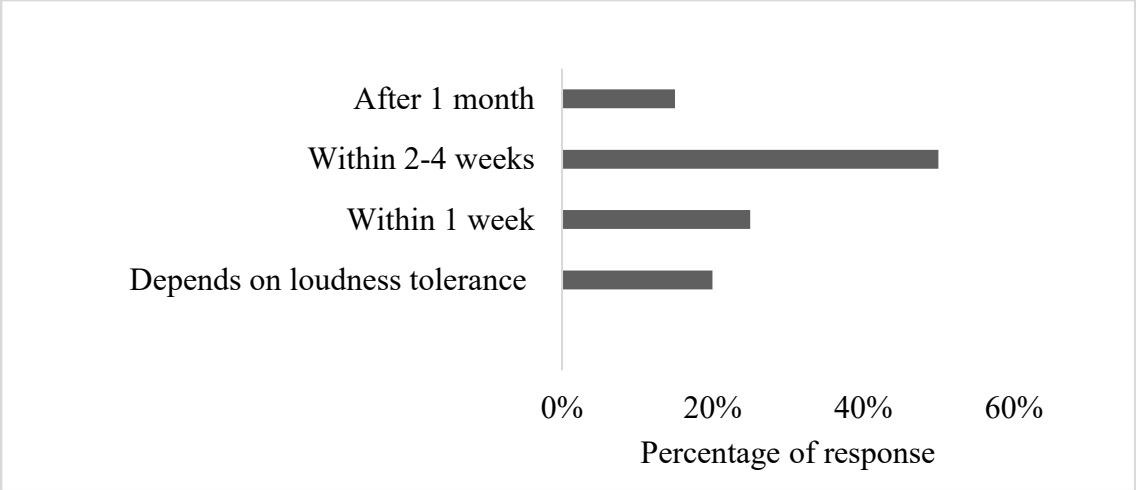
Audiometric Testing in Relation to Switch-on. Rather than being a routine process, audiometric testing during switch-on was recommended by 90% of participants,

based on clinical indications such as the adult population, Auditory Neuropathy Spectrum Disorder (ANSD), and cases involving Electro-Acoustic Stimulation (EAS).

First Follow-Up Visit After Switch-On and Further Follow-Ups. The recommended schedule for the first follow-up visits after switch-on is depicted in Figure 4.2. The timing of the first follow-up visit may vary depending on individual patient factors such as initial auditory responses, loudness tolerance, prior hearing experience, and overall clinical progress (as reported by 25%). An earlier follow-up within one week may be recommended when closer monitoring is required, particularly in cases with uncertain initial responses or recent programming adjustments. Nevertheless, 70% of participants reported that the timing of the first follow-up visit is the same for both pediatric and adult CI recipients.

Figure 4.2

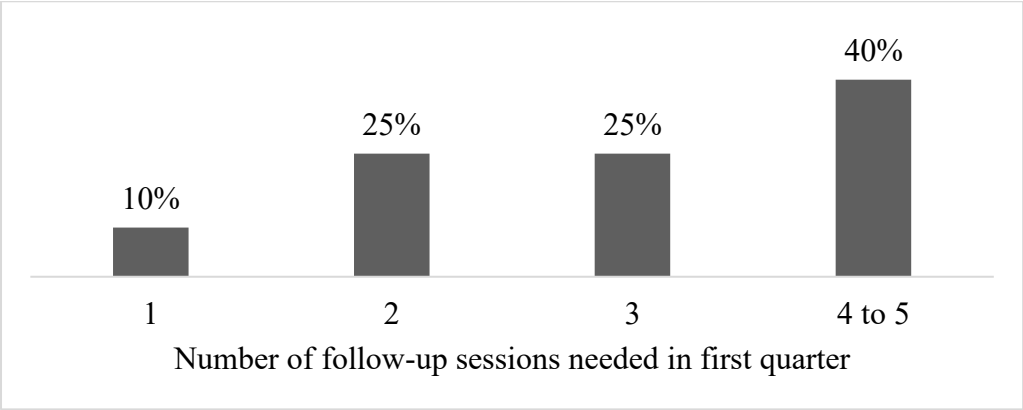
Bar graph showing the recommended first follow-up schedule after the initial switch-on



Approximately more than two follow-up sessions are required during the first three months after CI switch-on (as per the majority; 90%). After switch-on, the number of follow-up sessions during the first quarter may vary depending on individual patient progress, auditory adaptation, and mapping-related challenges. The distribution of follow-up sessions required in the first quarter is depicted in Figure 4.3.

Figure 4.3

The number of follow-up sessions needed in the first quarter



Bilateral CI Mapping. Additional considerations may be included during mapping compared to unilateral users. Loudness balancing across both ears may be performed to achieve comfortable, balanced binaural perception (55%), while a similar overall mapping approach may be applied to each ear (40%).

Bimodal CI Mapping. For bimodal users, mapping may involve the same overall approach (reported by 55%) as for unilateral CI users. Loudness matching between the CI and hearing aid ears may be performed (as per 35%), and latency delay adjustments may also be considered to support balanced auditory perception (reported by 20%).

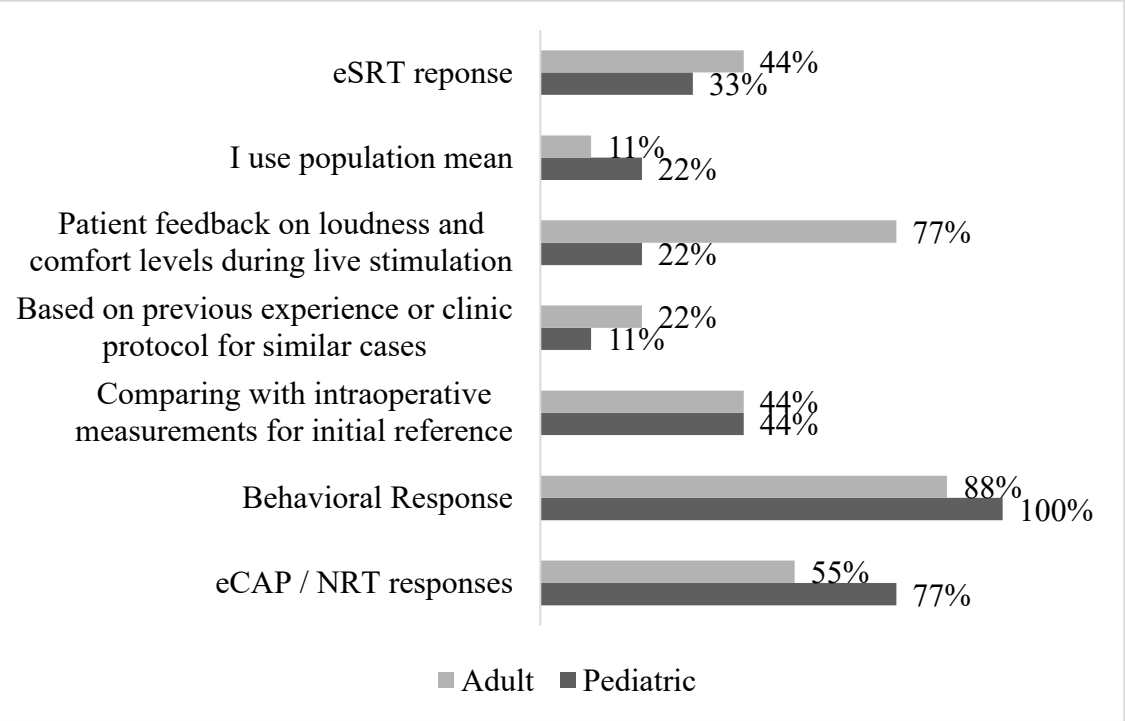
Setting LSLs and USLs. The methods for determining LSLs and USLs across the manufacturers (Cochlear Limited, MED-EL, and Advanced Bionics) recommended by the experts are shown in Figures 4.4a, 4.4b, and 4.4c. Instead of formal loudness scaling charts, behavioral responses (e.g., simple rating scales such as soft, medium, and loud) may be used to determine loudness levels during pediatric CI mapping (reported by 95%). In addition, 55% of participants reported not using loudness scaling charts in the pediatric population.

Whereas in the adult population, the loudness level selected using a loudness scaling chart is considered as the ‘comfortable level’ (as per 35%), ‘maximum comfortable

level- 1 current level below the USL' (as per 15%). In most cases, stimulation levels are set at or slightly below the USL to ensure comfortable listening. Loudness levels across individual electrodes may be measured, more commonly in adult CI recipients (reported by 20%).

Figure 4.4 a

Methods for determining LSLs and USLs in Cochlear Limited devices



Note: eSRT- electrically evoked stapedial reflex threshold, eCAP-electrically evoked compound action potential, NRT- neural response telemetry, LSL-lower stimulation level, USL- upper stimulation level.

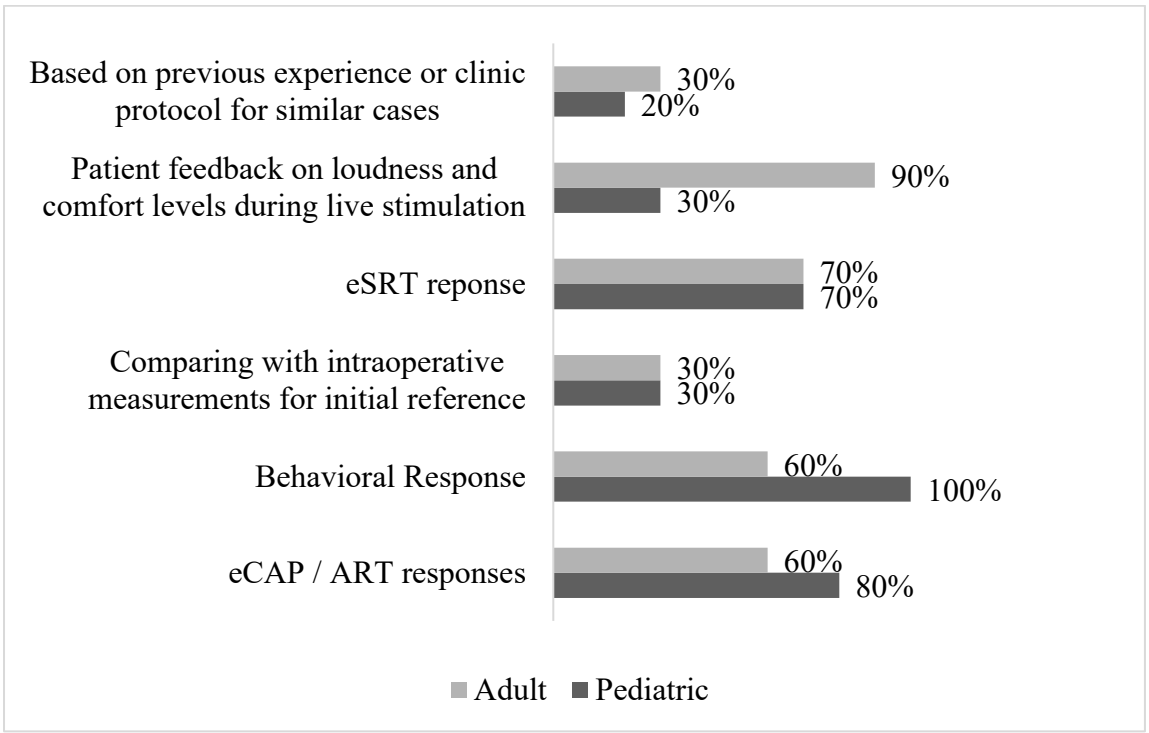
From Figure 4.4a, it is clear that behavioural responses are considered more important irrespective of age, followed by objective measures such as eCAP/NRT responses. These are recommended as an adjunctive tool during CI mapping (reported by 77% in pediatric and 55% in adult CI recipients), particularly as an initial reference for setting stimulation levels in non-cooperative pediatric recipients (as per 22%). In such

cases, T levels are often set above measured eCAP thresholds (according to 22%), while 33% of participants did not recommend the use of this measure.

In comparison, participants supported the use of eSRT responses for setting USL, with 44% in adults and 33% in pediatric populations, where C levels are typically set slightly below the measured eSRT threshold (e.g., 3–5 clinical levels below). If eSRT or eCAP measurements cannot be obtained for setting stimulation levels, behavioural or conditioned responses should be used as the primary alternative approach (as per 55%). Alternatively, Advanced NRT with increased pulse width (reported by 22%) or population mean values (reported by 22%) may be considered in selected cases during CI mapping.

Figure 4.4 b

Methods for determining LSLs and USLs in MED-EL devices

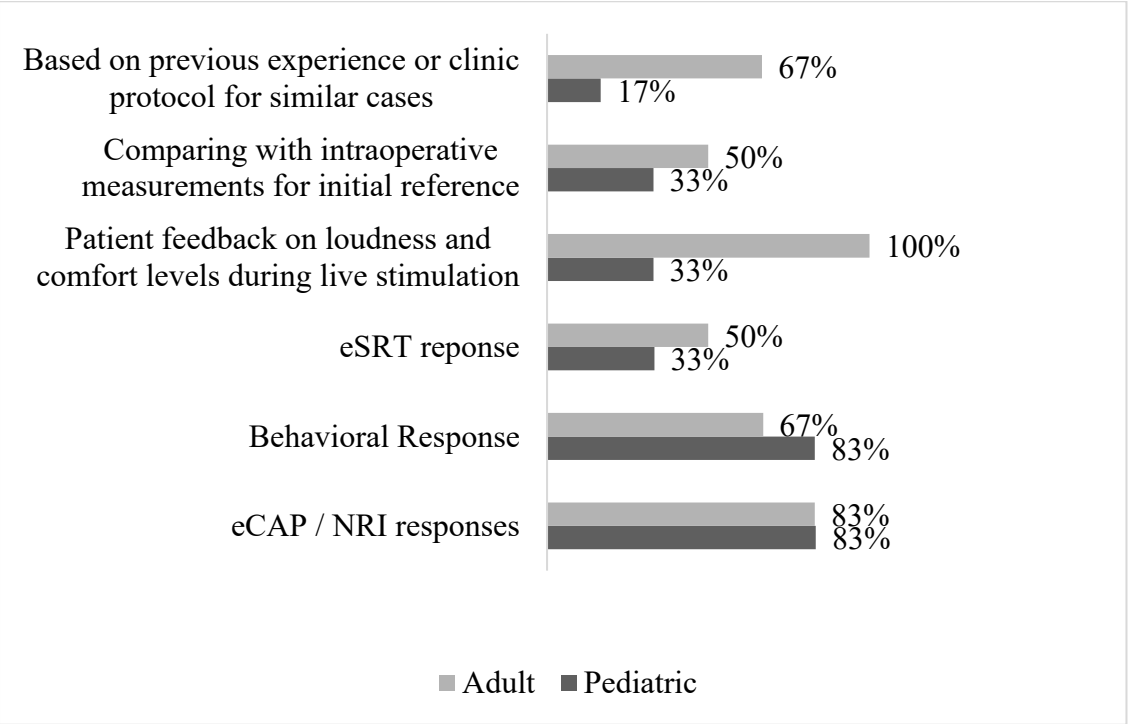


Note: eSRT- electrically evoked stapedial reflex threshold, eCAP-electrically evoked compound action potential, ART- auditory nerve response telemetry, LSL-lower stimulation level, USL- upper stimulation level.

From Figure 4.4b, it is clear that, similar to Cochlear Limited, all participants (100%) recommend behavioural responses for setting stimulation levels for pediatric CI recipients. In addition, patient feedback on loudness and comfort levels during live stimulation is recommended for consideration by 90% of participants during the mapping of adult CI recipients. During CI mapping, eCAP/ART responses are used to set stimulation levels (reported by 60% in adult and 80% in pediatric cases), whereas eSRT responses are more commonly used to set MCL (as per 70%), with MCL typically set approximately 3–5 clinical units below the measured eSRT threshold. For MED-EL CI mapping, THR levels may be locked at approximately 8% of the MCL (as per 80%), while locking THR levels at 10% of the MCL (as per 20%) may also be considered in selected cases. As observed with other manufacturers, if eSRT or eCAP measurements cannot be obtained for setting stimulation levels, behavioural methods should be used as the primary clinical approach during CI mapping as reported by all participants (100%).

Figure 4.4 c

Methods for determining LSLs and USLs in Advanced Bionics devices



Note: eSRT- electrically evoked stapedial reflex threshold, eCAP-electrically evoked compound action potential, NRI- neural response imaging, USL-upper stimulation level, LSL-lower stimulation level

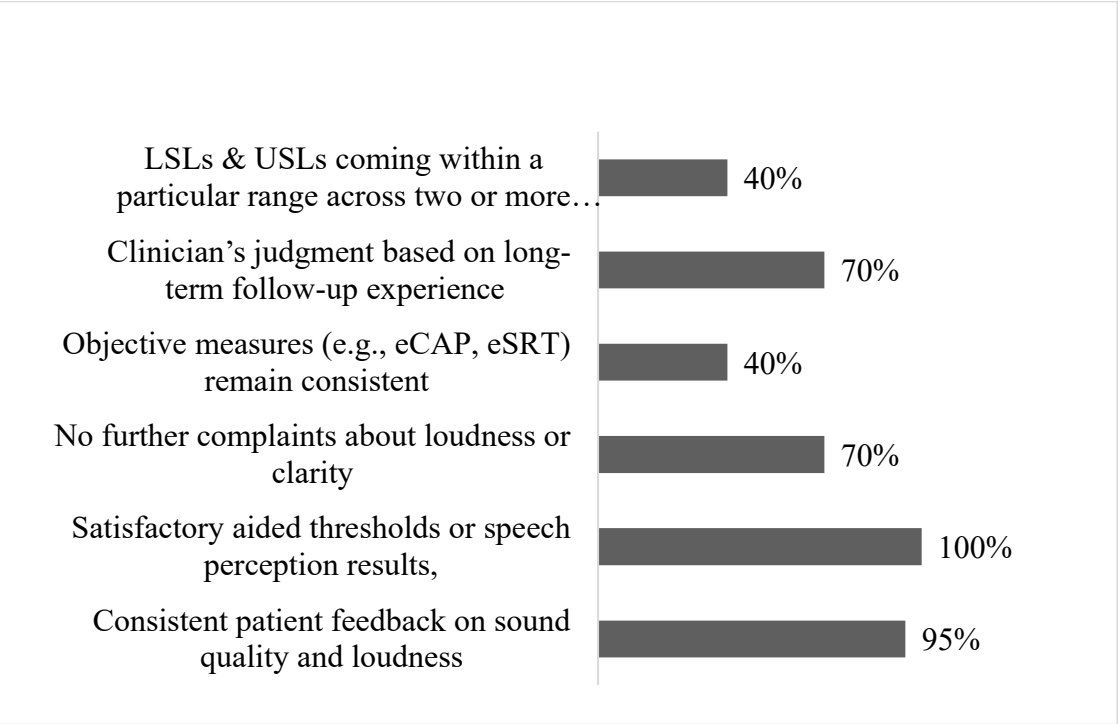
From Figure 4.4c, it is clear that, unlike Cochlear Limited and MED-EL, behavioural responses have the same importance as eCAP/NRI for the Pediatric CI recipients (reported by 83%) for setting the stimulation levels. In addition, patient feedback on loudness and comfort levels during live stimulation is recommended to be considered while mapping adult CI recipients by all participants (100%). Estimating “M level” from the eCAP can be done by applying a positive offset of approximately 20–40 current units (CU) above the t-NRI threshold (reported by 17%), or by starting at t-NRI + (10 to 15) CU, followed by behavioural assessment and gradual adjustment of comfort levels as needed.

eSRT responses may be recommended for setting M levels, with M levels often set at the minimum level at which the stapedius reflex is obtained (reported by 67%), although eSRT may not be routinely recommended for this purpose in all cases (as per 33%). Default settings for locking T level at 10% of the M level should generally be maintained during AB CI mapping as per all the participants (100%). Similarly, all participants (100%) agreed that, global adjustment in Live Speech mode followed by loudness balancing may be preferred for M levels in very young AB CI recipients, while single-channel (individual electrode) tone-burst stimulation may be preferred in adults or older children (reported by 83%), and Speech Burst stimulation across multiple channels may also be used as a default method (as per 67%). If eSRT or eCAP measurements cannot be obtained for setting stimulation levels, behavioural methods should be used as the next clinical approach during CI mapping (by 100% of participants), as in previous manufacturers.

Indicators of CI Map Stability and Optimisation. A CI map may be considered stable or optimised when aided thresholds and speech perception performance are satisfactory (according to all; 100%), and when the recipient provides consistent feedback regarding sound quality and loudness (reported by 95%). The absence of further complaints related to loudness discomfort or unclear sound perception may also suggest map stability. In addition, clinician judgment based on long-term follow-up experience and overall patient progress may contribute to determining whether the map is optimised (as per 70%). The participant's response regarding CI map stability or optimisation is depicted in Figure 4.5.

Figure 4.5

Criteria for cochlear implant map stability and optimisation



Note: eCAP- electrically evoked compound action potential, eSRT- electrically evoked stapedial reflex threshold, LSL-lower stimulation level, USL- upper stimulation level.

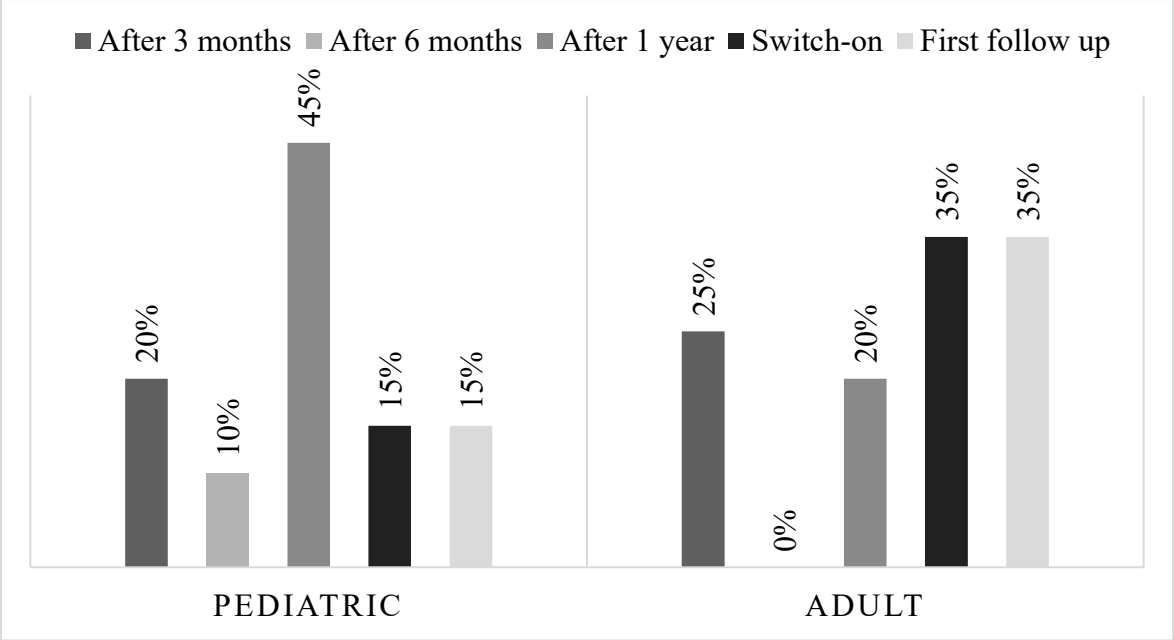
According to a few participants (15-20%), a map is stabilised when there are no significant fluctuations in electrode impedance, voltage measurements, and other findings across sessions. In clinical practice, minimal changes in USL values relative to the previous map (e.g., remaining within approximately 5 current levels or within 20 current levels in some cases) are also recommended. The presence of a sufficient dynamic range and the absence of significant changes in psychophysical measures across three consecutive sessions may further support the conclusion that the CI map is stable or optimised.

Timing of ALD Recommendation in CI Recipients. The timing of the recommendation may vary in both pediatric and adult CI recipients, as shown in Figure

4.6, depending on auditory progress, listening needs, communication difficulties, and clinician judgment.

Figure 4.6

Recommended timing for the introduction of assistive listening devices following cochlear implant



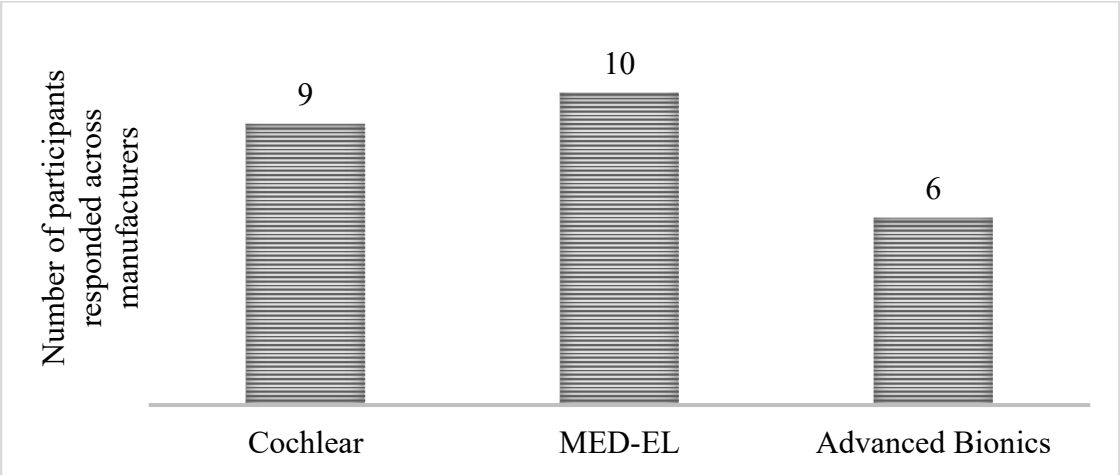
Of the 20 participants, 65% indicated involvement within a team-based clinical set-up. When CI recipients are managed by more than one audiologist within a clinical setup, consistency in mapping practices may be maintained through the use of shared patient mapping records (as per 35%), adherence to a standardised centre-specific mapping protocol (reported by 35%), and periodic team reviews or case discussions among audiologists involved in CI management (as per 15%).

4.2.2 Manufacture Specific Information

The following sections of the questionnaire contained responses for each manufacturer-specific detail, and participants were selected based on their experience. Figure 4.7 shows the number of participants who responded across the manufacturers. As shown in the figure, most audiologists work with multiple CI manufacturers.

Figure 4.7

The number of participants responded across manufacturers



4.2.2.1 Cochlear Limited

During the electrode impedance measurement, the custom stimulation mode (e.g., MP1+2) is preferred by all participants (100%), and the detailed view window is recommended by 55% of them, compared to the global (44%) and comfort (22%) windows. Population mean values may be considered in selected cases, such as when eCAP thresholds are unavailable or when inner ear anomalies are present (reported by 55%), and one expert also suggested this for young recipients and immediate switch-on cases.

Advanced NRT in the Custom Sound EP software is recommended to perform when eCAP responses are absent at the default pulse width (as per 77%). Advanced NRT is recommended by 33% of participants when pulse-width adjustments are required to obtain reliable neural responses. Pulse width may be modified in patients presenting with high electrode impedance values or facial stimulation during CI mapping (reported by 44%). Different pulse widths, such as 25 µs and 37 µs, may also be tested when eCAP responses are weak, inconsistent, or obscured by artefacts (as per 44%). A gradual increase in the dynamic range (DR) was recommended across the progressive maps during the

switch-on and follow-up sessions, with values increasing from 20-30 CU at the initial switch-on session to 25-50 CU during later follow-up visits, as shown in Table 4.1.

Table 4.1

Dynamic range values across switch-on and follow-up visits in Cochlear Limited devices

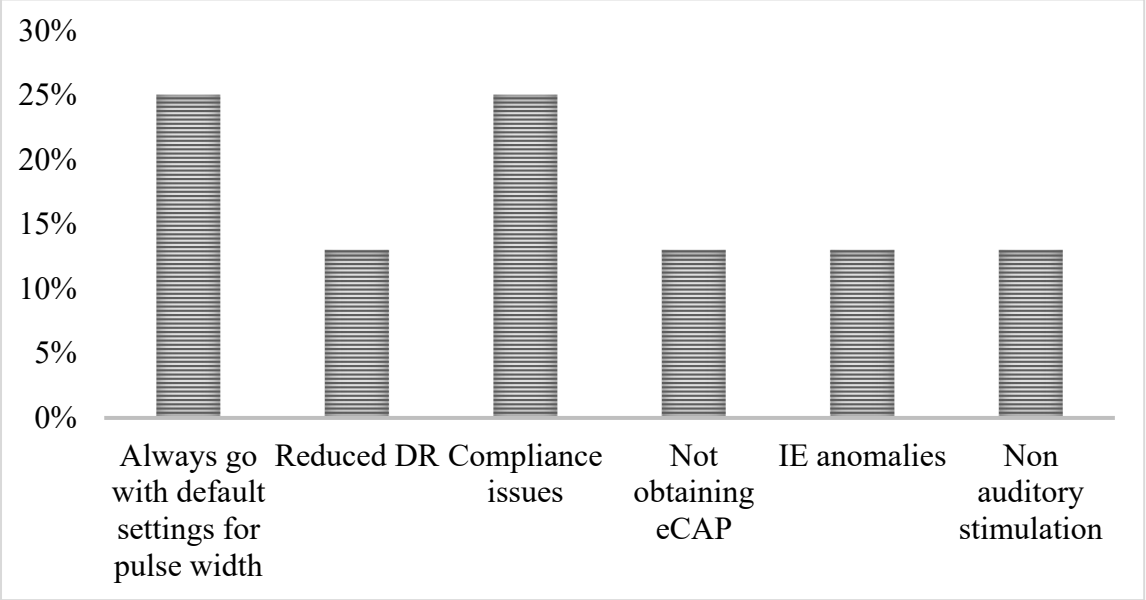
Sl.No	Mapping scenario	Dynamic Range Current Units
1	Switch-on Progressive map1	20-30
2	Switch-on Progressive map2	25-35
3	Switch-on Progressive map3	25-40
4	Switch-on Progressive map4	25-45
5	Follow up 1	25-45
6	Follow up 2	25-45
7	Follow up 3	25-50
8	Follow up 4	25-50
9	Follow up 5	25-50

Most participants (77%) reported that the default speech-processing strategy (ACE) is generally preferred in routine Cochlear CI mapping, except in cases such as ANSD and inner-ear anomalies, where modifications may be required. In contrast, for recipients with thin cochlear nerves (according to 44%) and for recipients concerned on battery consumption (as per 11%) who need lower stimulation rate, around 50% of participants preferred using default settings for stimulation rate (900pps), and if no/limited benefit with the pulse width and rate change, the number of maxima also needs to be changed (as per 11%) in case of thin nerve pathology. Otherwise, 77% agreed to use the default maxima setting (8). Default stimulation mode settings (e.g., MP1+2) should

generally be maintained during CI mapping by all participants (100%). Decisions regarding the default pulse width setting are depicted in Figure 4.8.

Figure 4.8

The recommendations for changing the pulse width setting

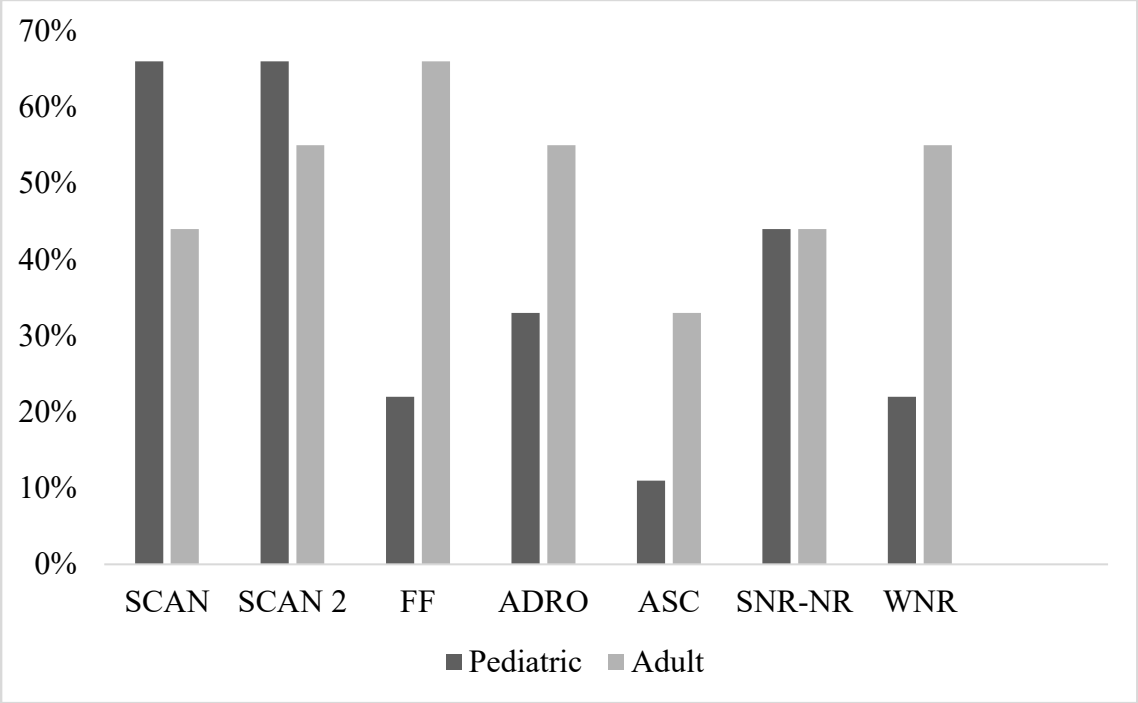


Note: DR-dynamic range, eCAP-electrically evoked compound action potentials, IE-inner ear anomalies.

Default volume adjustment settings should generally be maintained during CI mapping (reported by 88%), except in IE cases (as per 11%). Similarly, default frequency table power settings should generally be maintained (as per 88%), except when partial electrode insertion is used during CI mapping (according to 13%). Unlike these default loudness growth settings, volume, and sensitivity settings are generally maintained by all participants (100%). The recommended preprocessing strategies are shown in Figure 4.9 for both pediatric and adult CI recipients.

Figure 4.9

Pre-processing strategies for pediatric and adult Cochlear Limited cochlear implant recipients



Note: SCAN- Scene classifier, SCAN 2 – Automatic scene classifier 2, FF- Forward Focus, ADRO- Adaptive Dynamic Range Optimization, SNR-NR- Signal to Noise Ratio-based noise reduction, WNR- Wind Noise Reduction, ASC- Auto-Sensitivity Control

4.2.2.2 MED-EL

A gradual increase in the upper limit of MCL was recommended across the progressive maps during the switch-on and follow-up sessions, with values increasing from 20-25 qu at the initial switch-on session to 40-45 qu during later follow-up visits, as shown in Table 4

Table 4.2

Upper limit of USLs values across switch-on and follow-up visits in MED-EL devices

Sl.No	Mapping scenario	Upper Limit of MCL (Qu)
1	Switch-on Progressive map1	20-25
2	Switch-on Progressive map2	25-30
3	Switch-on Progressive map3	25-30
4	Switch-on Progressive map4	25-30
5	Follow up 1	30-35
6	Follow up 2	30-35
7	Follow up 3	30-35
8	Follow up 4	35-40
9	Follow up 5	40-45

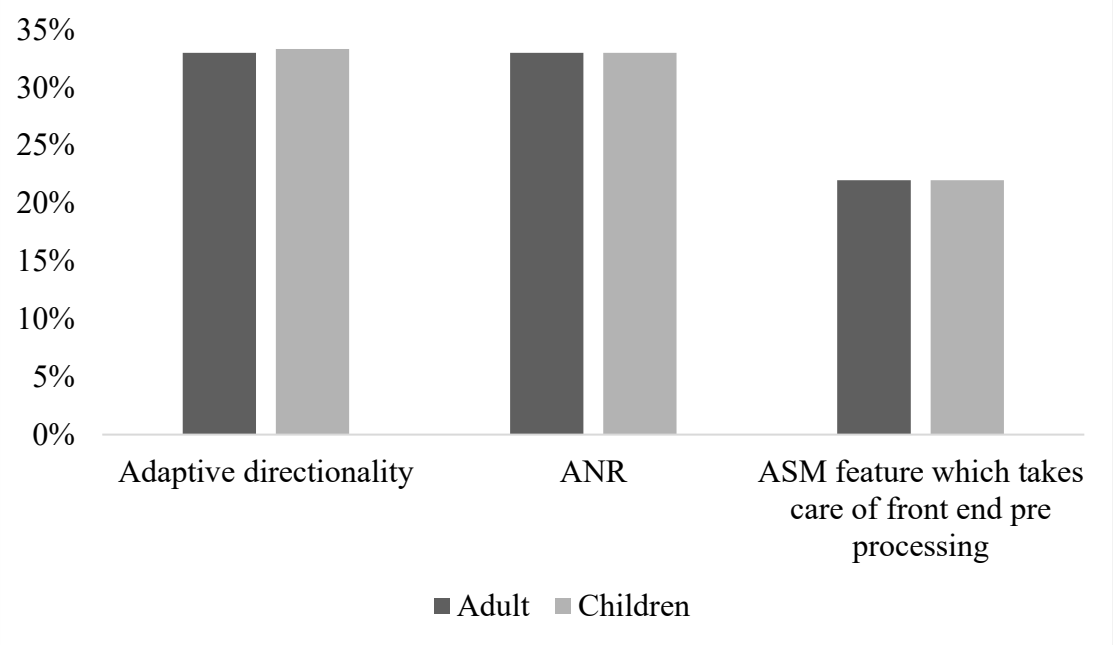
Note: MCL-most comfortable level, USLs-upper stimulation levels

All participants (100%) reported using the default settings for the following parameters: AGC compression ratio (3:1), wind noise reduction (default: “mild”), and volume mode (IBK). Most participants (90%) preferred default settings for AGC sensitivity (75% is the default setting) and MapLaw settings (default logarithmic, compression = 500). One expert among 10 participants recommended changes in the default setting of speech processing strategy (FS4) whenever necessary. However, increased sensitivity settings may be considered in selected cases (as per 11%), and higher MapLaw values (e.g., 750 or 1000) may be used in cases of inadequate loudness or reduced speech clarity (reported by 11%). With respect to frequency bands (logarithmic FS: 100–8500 Hz), it is recommended to retain the default setting (as per 90%). However, frequency-allocation adjustments may be required when electrode disabling is necessary (reported by 11%). Regarding microphone directionality (default: “Natural”), it should

generally be maintained (as per 80%), although it may be modified in adult recipients based on listening requirements (reported by 20%). All participants (100%) agreed on, except when CI recipients report difficulty with fan noise or wind noise during travel, default wind noise reduction settings should generally be maintained.

Figure 4.10

Pre-processing strategies for pediatric and adult MED-EL cochlear implant recipients



Note: ANR- ambient noise reduction, ASM- automatic sound management

4.2.2.3 Advanced Bionics

A gradual increase in the upper limit of M level was recommended across the progressive maps during the switch-on and follow-up sessions, with values increasing from below 100 charge units at the initial switch-on session to 250-300 charge units during later follow-up visits, as shown in Table 4.3

Table 4.3

Upper limit of M level values across switch-on and follow-up visits in Advanced Bionics devices

Sl.No	Mapping scenario	Upper Limit of M level (Charge units)
1	Switch-on Progressive map1	Below 100
2	Switch-on Progressive map2	100-150
3	Switch-on Progressive map3	100-150
4	Switch-on Progressive map4	100-150
5	Follow up 1	100-150
6	Follow up 2	150-200
7	Follow up 3	200-250
8	Follow up 4	200-250 /250-300
9	Follow up 5	250-300

All participants (100%) reported generally maintaining the default settings for parameters such as speech processing strategy, gain (default is 0 for all channels), Volume Max (default is 20%) & Min (default is 50 %), microphone sensitivity (default is 0 dB), audio mixing (default is 50/50 Mic/Aux), microphone mode (default is omnidirectional), filter settings (default is extended low), and AGC (default is 2- dual loop) during AB CI mapping.

Most participants (83%) also preferred retaining the default Pulse Width (APW I) and Input Dynamic Range (IDR) settings (default is 60 dB), while a smaller proportion (17%) reported making modifications based on specific clinical requirements. Pulse Width adjustments from APW I to APW II or manual modifications were mainly considered in cases approaching compliance limits due to high thresholds or elevated electrode

impedance values (17%). Likewise, some participants (17%) reported increasing the IDR to 70–80 dB for experienced users to provide a broader acoustic range and enhance music perception, while maintaining 60 dB for newly implanted users. The recommended preprocessing strategies are shown in Figure 4.11 for both pediatric and adult AB CI recipients. The overall results, presented as consensus statements, are shown in Table 4.4.

Figure 4.11

Pre-processing strategies for pediatric and adult Advanced Bionics cochlear implant recipients

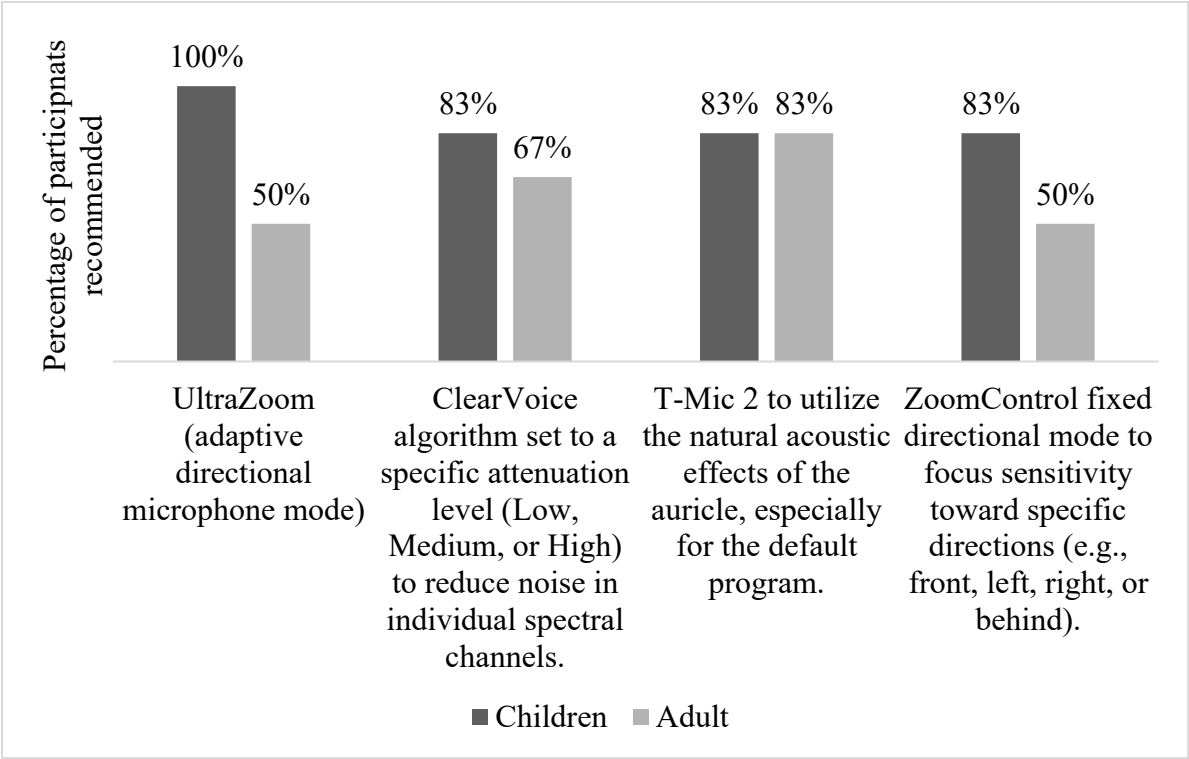


Table 4.4

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Clinical criteria for confirming readiness for switch-on and timing of switch-on	
1	*During switch-on, before connecting an implant to the software, it is necessary to make sure the 'readiness for switch-on', by reviewing the surgical site condition in terms of redness, swelling or signs of infection, ensuring adequate wound healing. It is also important to confirm the medical clearance or surgeon's approval before switch-on.*
2	*Consider the CI recipient's general health status, including the presence of illness or fever and behavioural state, to ensure readiness for switch-on*
3	*Reviewing clinical records, including intraoperative electrode impedance measurements, intraoperative objective measures (intraoperative eCAP or stapedial reflex findings and imaging reports), confirming the electrode placement, along with pre-implant CT/MRI findings, is needed before proceeding with activation.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Clinical criteria for confirming readiness for switch-on and timing of switch-on	
4	*Initial switch-on to be performed within 10-30 days for both pediatric and adult CI recipients, and can consider early CI switch-on (within 24 hours to 10 days post-surgery).*
5	*Pure tone audiometry (PTA) during switch-on is not routinely performed unless clinically indicated, as in cases with EAS, ANSD with peripheral normal hearing sensitivity, and in cooperating clients, including adult CI recipients.*
Electrode Impedance measurement	
6	*After connecting the device to the software, it is always recommended to start with the electrode impedance measurement, and if abnormal or concerning electrode impedance patterns are observed, it is always recommended to re-run the electrode impedance assessment. If that is showing consistently deviant electrode impedance values from the manufactures normal range including persistently high electrode impedance values (e.g., open or short circuit electrodes), identified with an extra-cochlear electrode position, when software recommendations indicate or default alert systems indicate poor electrode function, and based on the objective measures (e.g., eCAP, eSRT) also showing abnormal stimulation levels compared to neighboring electrodes; then it should be considered for deactivation.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Electrode Impedance measurement	
7	*When concerning electrode impedance patterns are observed, magnet strength should be re-checked to ensure appropriate communication and coil retention.*
8	*Other factors like URTI, ear pain or other medical conditions should also be considered while interpreting the electrode impedance values. In addition, 'electrode conditioning' is also recommended as a troubleshooting process for concerning electrode impedance patterns.*
9	*There is no difference in the troubleshooting process concerning electrode impedance values in the adult and pediatric populations.*
10	*Electrode impedance should be measured at every follow-up visit after the initial stabilization period.*
Progressive maps setting and other challenges during switch-on	
11	*Progressive maps may not be routinely applicable in all cases.*
12	*The use of progressive map during the switch-on determined based on individual patient factors including age, clinical condition, listening responses and access to the regular follow-up services.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Progressive maps setting and other challenges during switch-on	
13	*Major challenges encountered during the initial CI switch-on include parental/caregiver anxiety or limited understanding regarding the procedure and outcome, difficulty in obtaining reliable responses while setting LSLs and USLs, especially in young children and uncooperative clients, and discomfort or intolerance to initial electrical stimulation.*
14	*Rarely during initial activation, it is also possible to come across facial nerve stimulation or non-auditory sensation during mapping, software, or connectivity problems with respect to the programming system and among adult CI recipients' anxiety about the speech perception outcome is another challenge to be faced during switch-on.*
Follow-up CI mapping schedules	
15	*Following switch-on, the timing of the first follow-up visit is typically scheduled between two to four weeks, irrespective of the age of the CI recipient. If closer monitoring is required, it is also recommended to do an earlier follow-up within 1 week.*
16	*This timing can also vary based on the individual CI recipient's initial auditory responses, loudness tolerance, overall hearing progress, and prior hearing responses. However, it is similar across both adult and pediatric CI recipients.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Follow-up CI mapping schedules	
17	*On average, four to five follow-up sessions may be required during the first quarter post CI switch-on. This number can vary based on individual patient progress, auditory adaptation and mapping-related challenges*
Bilateral and bimodal CI mapping	
18	*During bilateral CI mapping, it is important to consider loudness balancing across both ears to achieve comfortable, balanced binaural perception. Other than that, the overall mapping approach will be similar for each ear.*
19	*For bimodal CI users, ensuring loudness balancing between the CI and hearing aid ears should be performed, and latency delay adjustments should also be considered to support balanced auditory perception.*
Determination of LSLs and USLs, including objective measures in CI mapping: General	
20	*Behavioural responses are mainly recommended to determine LSLs and USLs across the manufacturers irrespective of the age. Even if objective measures cannot be obtained to assist in setting the stimulation levels, then the first line of approach will be behavioral methods.*
21	*Patient feedback regarding loudness and comfort during live stimulation is also considered, especially in adult CI recipients.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Determination of LSLs and USLs, including objective measures in CI mapping: General	
22	*If using the loudness scaling chart to set loudness levels in a pediatric CI recipient, it is possible to directly correlate it with behavioural comfort levels, mostly using simple rating scales (e.g., Three levels: soft, medium, and loud).*
23	*In adult CI recipients, the loudness level selected is considered the comfortable level or the maximum comfortable loudness level. In majority of the cases stimulation levels can be set at the level or slightly below the USL (one to three current levels) for ensuring comfortable listening.*
24	*Loudness levels are usually not measured across all the electrodes; it is applicable only when the assessment is performed during the initial switch-on, or on adult CI recipients, or when the CI recipient has become familiar with the hearing through CI, or when non-auditory stimulation is suspected.*
25	*Furthermore, intraoperative measurements may also serve as an initial reference during programming.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
	Methods for determining LSLs and USLs- Cochlear Limited
26	*Objective measurements, such as eCAP/NRT responses, may also be commonly used to assist in determining these levels in pediatric CI recipients and non-cooperative clients, with LSLs/T levels often set above the measured eCAP thresholds and USLs/C levels typically set slightly below the measured eSRT threshold (three to five clinical levels below).*
27	*Population mean values may guide the determination of appropriate stimulation levels, in selected cases, such as when eCAP thresholds are not obtainable or when inner ear anomalies are present.*
	Methods for determining LSLs and USLs- MED-EL
28	*Objective measurements like eSRT responses may be recommended for setting USLs/Most Comfortable Levels (MCL), with MCL often set at the minimum level at which eSRT is obtained and above the level of eCAP threshold.*
29	*LSLs/Threshold (THR) levels may be locked at 8% of the MCL, while locking THR levels at 10% of the MCL may also be considered in selected cases.*
30	*While doing mapping based on eCAP/ART, based on the ART threshold a base map will be created and then adjust with the behavioural response if reliable.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
	Methods for determining LSLs and USLs- Advanced Bionics
31	*Global adjustment in Live Speech mode followed by loudness balancing is preferred for measuring USLs/M levels in very young CI recipients, while single-channel (individual electrode) tone-burst stimulation is preferred in adults or older children ,and Speech Burst stimulation across multiple channels may also be used as a default method.*
32	*Objective measurements like eSRT responses may be recommended for setting USLs/M levels, with M level often set at the same level at which eSRT obtained.*
33	*M levels may be estimated from eCAP/NRI/t-NRI responses by applying a positive offset of approximately 20–40 CU above the t-NRI threshold or by starting at t-NRI +10–15 CU followed by behavioral assessment and gradual adjustment of comfort levels as needed, while monitoring behavioral responses during increases in stimulation levels.*
34	*LSLs/T level may be locked at 10% of the M level, generally be maintained during AB CI mapping*
	Approaches to Maintaining and Modifying default CI parameters across the manufacturers
	Default parameters- Cochlear Limited
35	*Custom stimulation modes (e.g., MP1+2) may be used during electrode impedance measurements and during CI mapping*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Approaches to Maintaining and Modifying default CI parameters across the manufacturers	
Default parameters- Cochlear Limited	
36	*Detailed view windows may be preferred during CI mapping than Global View windows and Comfort View settings to facilitate efficient visualization and programming.*
37	*Advanced NRT may be performed when eCAP responses are absent/ weak/inconsistent with the default pulse width and it also recommended to perform advanced NRT in cases with high electrode impedance and facial nerve stimulation.*
38	*It is recommended to go with default settings for the speech coding strategy except in ANSD and inner ear anomaly cases.*
39	*Unlike the default rate of stimulation, for individuals with thin cochlear nerve and cases concerning battery consumption, it is recommended to go with lower stimulation rate.*
40	*And if not getting benefit with the pulse width and rate change, in inner ear anomaly cases it is recommended to go with the change in default maxima setting.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Approaches to Maintaining and Modifying default CI parameters across the manufacturers	
Default parameters- Cochlear Limited	
41	*Default pulse width settings may generally be maintained during CI mapping; however, pulse width adjustments may be considered in cases of reduced dynamic range, absent eCAP responses, inner ear anomalies, non-auditory stimulation, or other compliance-related issues*
42	*Default volume adjustment settings should generally be maintained except in inner ear anomaly cases.*
43	*Default loudness growth settings and volume and sensitivity settings will not change in any circumstances.*
44	*Default frequency table power settings will be maintained in all cases except partial insertion cases.*
45	Based on the listening needs the following pre-processing features can be used for pediatric CI recipients SCAN>SCAN-2>SNR-NR>FF>ADRO>WNR.
46	Similarly for Adult recipients it is recommended in the following order SCAN=SCAN 2=FF>ADRO=WNR>SNR-NR>ASC

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Approaches to Maintaining and Modifying default CI parameters across the manufacturers	
Default parameters- MED-EL	
47	*If by any chance electrode needs to be disabled, then it is required to manipulate the default settings for the frequency bands.*
48	*AGC sensitivity setting can be changed from default 75% to 100% if clinically indicated.*
49	*Unless it is getting higher MapLaw values with inadequate loudness and speech clarity, it is recommended to go with the default setting.*
50	*Based on the listening requirement, the default setting for microphone directionality can be manipulated.*
51	*Default settings for the speech coding strategy, AGC compression ratio, volume mode, and wind noise reduction will generally be maintained.*
52	Adaptive Directionality, Ambient Noise Reduction/ANR and ASM front-end preprocessing features can be enabled for pediatric and adult CI recipients.

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Approaches to Maintaining and Modifying default CI parameters across the manufacturers	
Default parameters- Advanced Bionics	
53	*Pulse Width adjustments from APW I to APW II or manual modifications were mainly considered in cases approaching compliance limits due to high thresholds or elevated electrode impedance values.*
54	*Likewise, increasing the IDR to 70–80 dB in experienced users to provide a broader acoustic range and enhance music perception can be considered, while continuing to maintain 60 dB IDR for newly implanted users.*
55	*Other than these, the default settings for the speech coding strategy, gain for the channels, volume max and min, microphone sensitivity, audio mixing, microphone mode, filter setting, and AGC 2-dual loop will generally be maintained.*
56	*Based on the listening needs the following pre-processing features can be used for pediatric CI recipients Ultrazoom>clear voice=T-mic 2=zoom control.*
57	*Similarly for adult it is recommended as T-mic 2> clear voice> Ultrazoom=zoom control.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Indicators of CI Map Stability and Optimisation	
58	*A CI map is considered to be stable or optimised when the aided thresholds and speech perception performance are satisfactory, and also when the CI recipient provide consistent feedback regarding the quality of sound and loudness.*
59	*The absence of further of complaints related to the loudness discomfort or unclear sound perception can also be considered as a stabilised map.*
60	*The judgement of the clinician based on long-term follow-up experience and overall patient progress may contribute to determine whether the map is stable or optimised.*
61	*In other words, 'stabilised map' can also be defined as when there are no significant fluctuations in electrode impedance levels, voltage measures, and other findings across sessions*
62	*In clinical practice, LSLs and USLs coming within a particular range across two or more visits, with sufficient dynamic range, are also recommended as a stabilised map.*
63	*A CI map is considered to be stable or optimised when the aided thresholds and speech perception performance are satisfactory, and also when the CI recipient provide consistent feedback regarding the quality of sound and loudness.*

Table 4.4 (Continued)

Consensus statements on cochlear implant mapping procedures

Sl.No	Consensus Statements
Timing of ALD Recommendation in CI Recipients	
64	*The timing for recommending ALDs for pediatric CI recipients varies depending on the child's auditory progress, listening needs and clinical judgment. When the recipient needs additional listening support, ALDs can recommend them at the time of initial switch-on or during the first follow-up session.*
65	*Similarly, for adult CI recipients, the recommendations for ALDs vary depending on communication needs, listening difficulties, and clinical judgement.*
Consistency in CI Mapping	
66	*When the mapping procedure is managed by more than one clinician within a centre, to overcome problems with consistency in mapping, it is recommended to follow a standardised centre-specific protocol, shared patient mapping records, and periodic team reviews or case discussions among the audiologists involved in CI mapping***.**

Note: CI - cochlear implant, CT - computed tomography, MRI - magnetic resonance imaging, EAS - electric-acoustic stimulations, ANSD - auditory neuropathy spectrum disorder, PTA - pure tone audiometry, eCAP - electrically evoked compound action potential, eSRT - electrically evoked stapedius reflex threshold, URT I - upper respiratory tract infection, LSL - lower stimulation level, USL - upper stimulation level, NRT - neural response telemetry, THR - threshold level, MCL - most comfortable level, ART- auditory response telemetry, NRI - neural response imaging, t-NRI - threshold neural response imaging, CU - clinical units, MP1+2 - monopolar 1+2 stimulation mode, SCAN - Scene classifier, SCAN 2 – Automatic scene classifier 2, FF- Forward Focus, ADRO - Adaptive Dynamic Range Optimization, SNR-NR - Signal to Noise Ratio-based noise reduction, WNR - Wind Noise Reduction, ASC - Auto-Sensitivity Control, AGC - Automatic Gain Control, ANR - Ambient Noise Reductio, ASM - Automatic Sound Management, APW - Auto Pulse Width, IDR - Input Dynamic Range, T-Mic - Tele-Microphone, ALD- assistive listening device.

Chapter V

Discussion

CI mapping is widely considered the primary determinant of post-implant outcome, even though it is the least standardised. The present study aimed to address the variability in the CI programming procedure across clinicians. A uniform guideline for CI mapping procedures is necessary in India, a country with diverse aspects. Many previous studies have addressed candidacy and outcome measures in the CI field, along with protocols, but have given less emphasis to programming-related aspects of CI. The present study identified areas of strong agreement and aspects of clinical variability using a consensus-based approach. Several mapping practices, in general and manufacturer-wise, showed greater agreement among participants. However, variability was also evidently present in some items.

The following section of the discussion examines the gap between literature-based recommendations and their implementation, as revealed by the study's results. The discussion included the consensus statement as per the expert's recommendation, in general, and manufacturer-specific information. The major factor to be considered is that this study included 20 participants from various parts of India to analyse the CI mapping procedures they follow; thus, this is cross-sectional information on the currently recommended fitting procedure by the majority of participants. It is not recommended to treat this as a rigid rulebook, since technological evolution will inevitably lead to changes across all aspects, even in CI (Browning et al., 2020). The discussion is arranged from pre-switch-on preparation, switch-on, to mapping.

5.1 Clinical Criteria for Confirming Readiness for Switch-On

- *During switch-on, before connecting an implant to the software, it is necessary to make sure the 'readiness for switch-on', by reviewing the surgical site condition in terms of redness, swelling or signs of infection, ensuring adequate wound healing. It is also important to confirm the medical clearance or surgeon's approval before switch-on.*
- *Consider the CI recipient's general health status, including the presence of illness or fever and behavioural state, to ensure readiness for switch-on.*

Typically, it is recommended to wait for the surgical site to heal before activating the CI. This delay between surgery and switch-on is intended to address concerns such as post-operative oedema, infection, intracochlear inflammation and fibrosis, and possible displacement of the internal magnet (Roux-Vaillard et al., 2020). Chen et al. (2015) also emphasised the importance of relying on post-operative healing status, absence of complications and the surgeon's clearance before early activation. The AAA guidelines (Messersmith et al.,2019) also discussed multidisciplinary post-operative management, medical follow-up, wound monitoring and appropriate candidacy for activation or switch-on. Coelho et al. (2023) highlight post-operative assessment, medical clearance, and factors determining suitability for switch-on, irrespective of the waiting period (readiness for early switch-on within 24 hours). All these studies confirm the importance of medical clearance to ensure readiness for CI activation.

Wolfe and Schafer (2015) explained the importance of behavioural readiness, attention, fatigue, illness and patient cooperation during programming sessions (not only during switch-on sessions), especially in pediatric CI recipients. Similarly, Browning et al. (2020) and Vaerenberg et al. (2014b) discuss patient-specific considerations and the need

to adapt procedures to the recipient's condition and level of cooperation. In support of this, the AAA guidelines (Messersmith et al., 2019) also highlighted the importance of the patient's readiness, behavioural cooperation, and overall clinical condition during CI programming and follow-up.

- *Reviewing clinical records, including intraoperative electrode impedance measurements, intraoperative objective measures (intraoperative eCAP or stapedial reflex findings and imaging reports), confirming the electrode placement, along with pre-implant CT/MRI findings, is needed before proceeding with activation.*

CIGI guidelines, perfectly portraying the importance of intraoperative measurements, including imaging, for confirming the electrode placement during the surgery, in addition to the electrophysiological tests (Vishwakarma & Mohandas, 2018). Intra-operative measures enable early identification of potential issues that may require postoperative monitoring or management (Alzhrani et al., 2024). If any abnormality occurs during intraoperative time, the surgeon will take a call and do the needful; if it occurs during the post-operative period, it is in the hands of the audiologist involved in the switch-on procedures (Vishwakarma & Mohandas,2018). Pre-implant radiological reports to be reviewed to confirm the inner ear anomalies as reported in the literature (Sennaroğlu & Demir Bajin, 2017; Vishwakarma & Mohandas,2018). Similarly, the AAA guidelines highlight the importance of reviewing surgical, audiological, radiological, and electrophysiological assessment findings during post-operative programming (Messersmith et al., 2019).

Reviewing intra-operative imaging, including X-ray, is recommended to confirm the location and position of the electrode array (Bettman, Van Olphen, et al., 2003; Czerny

et al., 2000; Lawson et al., 1998b; Marsh et al., 1993b; Shapiro & Bradham, 2012; Todd & Ball, 2004). Intra-operative electrode impedance should be reviewed to confirm electrode functionality and may provide some predictive utility. However, it should not be considered sufficient for confirming electrode array placement, as electrode impedance values can still be obtained even when electrode contacts are located outside the cochlea (Busby et al., 2002; Goehring et al., 2013). Similarly, the presence of intraoperative electrically evoked stapedial reflex also indicates the integrity of both the ascending and descending pathways of the stapedial reflex arc (Gordon et al., 2004; Stephan & Welzl-Müller, 2000; Wiley & Fowler, 1997). Mason et al. (2001) demonstrated that intraoperative eCAP findings significantly correlate with the early behavioural T levels and eABR findings, supporting the importance of reviewing intraoperative objective measures before CI activation.

5.2 Switch-On Timing

- *Initial switch-on to be performed within 10-30 days for both pediatric and adult CI recipients, and can consider early CI switch-on (within 24 hours to 10 days post-surgery).*

The traditional recommendation for initial activation timing of ~10-30 days duration (Coelho et al., 2023; Vaerenberg et al., 2014b) was recommended by the majority of the experts**,** however, improved surgical techniques, including shorter surgeries, smaller incisions, and reduced hospital stays, now support immediate activation or early activation as CI recipients recover faster than before (Coelho et al., 2023; Marsella et al., 2014; Roux-Vaillard et al., 2020). Only a few of the present study's participants emphasised on next-day CI activation, which is an evident change in clinical protocols (Selvaratnam & Teagle, 2025; Sunwoo et al., 2021) unlike the result of Vaerenberg et al. (2014b) global survey showing traditional waiting period recommendation. There are no guidelines clearly

recommending waiting for almost 1 month. Concerns about wound healing, magnet displacement, and electrode impedance variation have been reported (Marsella et al., 2014). The early switch-on considerations are not only feasible but also provide real-life benefits for the client and family (Coelho et al., 2023), and the literature reports that electrode impedance drop was even faster in the early CI activation group (Saoji et al., 2022) compared to the traditional approach.

The literature indicates that only a few per cent of participants are unable to tolerate early CI activation (Saoji et al., 2022); as a result, there is a need for improved surgical practices and technical modifications. Further, early CI activation did not interfere with wound healing or fitting parameters, suggesting it can be considered for CI recipients based on individual preferences (Alsabellha et al., 2014; Chen et al., 2015; Wolf-Magele et al., 2015). Although it is not recommended by the majority of current study participants, it provides psychological benefits to the CI recipient and the caregiver by ensuring that the device is working properly prior to discharge, which helps them believe in successful outcomes (Saoji et al., 2022). Chen et al. (2015) found that early activation resulted in significant improvement in hearing after surgery. In alignment with this, Sun et al. (2019) also reported significantly better speech perception outcomes during the first month after surgery, although no significant difference was obtained between the early activation group and the delayed activation group after three months. Similarly, authors reported that early activation did not negatively affect speech perception outcomes, with both early and conventional activation groups showing comparable auditory performances over time (Marsella et al., 2014; Roux-Vaillard et al., 2020). Thus, the varied responses from the participants in the current study imply that this is not a crucial factor in the CI journey.

- *Pure tone audiometry (PTA) during switch-on is not routinely performed unless clinically indicated, as in cases with EAS, ANSD with peripheral normal hearing sensitivity, and in cooperating clients, including adult CI recipients.*

Similar to what was reported in Vaerenberg et al. (2014b) survey, only 10% of the experts recommended performing the PTA procedure during switch-on, but it was not mentioned under what circumstances it was performed in that study, here in the present study, clinicians recommended performing the PTA procedure in cases with EAS. Although it is not directly recommended, there are studies performed PTA during, studies have been performed on PTA during the first fitting session in EAS-type CI recipients (Bruschke et al., 2023; Haumann et al., 2025).

5.3 Electrode Impedance Measurement

- *After connecting the device to the software, it is always recommended to start with the electrode impedance measurement, and if abnormal or concerning electrode impedance patterns are observed, it is always recommended to re-run the electrode impedance assessment. If that is showing consistently deviant electrode impedance values from the manufactures normal range including persistently high electrode impedance values (e.g., open or short circuit electrodes), identified with an extra-cochlear electrode position, when software recommendations indicate or default alert systems indicate poor electrode function, and based on the objective measures (e.g., eCAP, eSRT) also showing abnormal stimulation levels compared to neighboring electrodes; then it should be considered for deactivation.*
- *When concerning electrode impedance patterns are observed, magnet strength should be re-checked to ensure appropriate communication and coil retention.*

- *Other factors like URTI, ear pain or other medical conditions should also be considered while interpreting the electrode impedance values. In addition, 'electrode conditioning' is also recommended as a troubleshooting process for concerning electrode impedance patterns.*
- *There is no difference in the troubleshooting process concerning electrode impedance values in the adult and pediatric populations.*
- *Electrode impedance should be measured at every follow-up visit after the initial stabilization period.*

Wathour et al. (2021) and Vaerenberg et al. (2014b) reported that electrode impedance measurements routinely performed at the beginning of each CI mapping sessions and repeated when abnormal patterns are observed to ensure appropriate electrode functioning. Henkin et al. (2006) demonstrated that electrode impedance values change across sessions and require continuous monitoring during CI mapping. Compared to the intra-operative measures of electrode impedance, there will be a rapid increase during the initial switch-on which then gradually reduce in both pediatric and adult CI recipients (Henkin et al., 2006; Hughes et al., 2001), then later on the formation of an hydride layer will gradually reduce the electrode impedance (Brummer & Turner, 1977), in order to see the trend it is essentially required to do a consistent electrode impedance check before starting with the setting of LSLs and USLs. Electrode impedance measurements are influenced by factors such as the electrode-tissue interface, the surrounding fluid environment and the resistance of electrode contacts and lead wires (Dagkiran & Tanrisever Pehlivan, 2026)

Higher electrode impedance values result in greater voltage across the electrode-tissue interface, which may lead to saturation of the current source and subsequently reduce the dynamic range of stimulation (Wilk et al., 2016). Increased electrode voltage will contribute to higher energy consumption, thereby reducing battery life, which is only one consequence of abnormal electrode impedance measurements and these concerns are particularly pointing towards the troubleshooting-related decisions to be taken by audiologists who are going to handle such circumstances.

When abnormal or concerning electrode impedance patterns are observed, repeated electrode impedance measurements are recommended to confirm the findings. Even then, the problem persists; individual electrode circuit failure may lead to reduced sound perception, non-auditory stimulation, and may even represent an early sign of progressive device malfunction (Carlson et al., 2010). Then the primary level of troubleshooting will be deactivating the electrode, and at a later level, it would indicate reimplantation (for declining performance and implants with three or greater individual circuit failures) (Carlson et al., 2010). As per the reference guide of Cochlear Limited (2023), if some electrodes are ‘out of compliance’ at the initial device activation, then it is recommended that the map needs to be modified to bring this into compliance and then only the deactivation of the electrode is taken into account. Vaerenberg et al. (2014b) survey also indicated that the most common reason for deactivating the electrode is the abnormal electrode impedance pattern, and also in cases with extracochlear location, and to an extent, non-auditory stimulation. It is also reported in the literature that there is no difference in the troubleshooting procedures based on the age of the recipient (Fielden & Kitterick, 2016; Wathour et al., 2021)

5.4 Progressive Map during Initial Switch-On and Other Challenges During Switch-On

- *Progressive maps may not be routinely applicable in all cases.*
- *The use of progressive map during the switch-on determined based on individual patient factors including age, clinical condition, listening responses and access to the regular follow-up services***.**

  Progressive maps are not universally recommended; their use depends entirely on the fitting approach and the patient's profile, including the recipient's auditory perception and participation ability, especially in the pediatric population (Chinnici, 2006). The AG Bell recommended protocol also states that the remapping schedule depends on age and individual factors, such as access to regular follow-up sessions (Alexander Graham Bell Association, 2014). Not only in protocols, but progressive maps are also routinely recommended by >70% of participants in the Vaerenbeg et al. (2014b) survey, irrespective of age, unlike the partial agreement among participants in the current study. Gradual accommodation to electrical stimulation is considered good before moving on to the next higher level. However, some clinicians do not agree with this statement, as they do not systematically increase stimulation levels.
- *Major challenges encountered during the initial CI switch-on include parental/caregiver's anxiety or limited understanding regarding the procedure and outcome, difficulty in obtaining reliable responses while setting LSLs and USLs, especially in young children and uncooperative clients, and discomfort or intolerance to initial electrical stimulation.*
- *Rarely during initial activation, it is also possible to come across facial nerve stimulation or non-auditory sensation during mapping, software, or connectivity problems with respect*

to the programming system and among adult CI recipients' anxiety about the speech perception outcome is another challenge to be faced during switch-on.

Previous literature also identified challenges commonly encountered during the initial stimulation period. Maintaining a comfortable and supportive environment is considered important in pediatric recipients, as obtaining reliable behavioural response during the setting of stimulation levels can be difficult in young children or uncooperative clients (Shapiro & Bradham, 2012). Studies also emphasised the importance of a multidisciplinary team during the initial programming sessions to help reduce parental anxiety and improve understanding regarding the procedure and expected outcomes (Shapiro & Bradham, 2012).

The literature further reports that, although less common, non-auditory stimulation, such as facial nerve stimulation, may occur during initial activation as a challenge, particularly when extracochlear electrodes or abnormal stimulation patterns are present (Shapiro & Bradham, 2012). Technical issues with software or programming system connectivity may also complicate the switch-on process (Shapiro & Bradham, 2012).

5.5 Follow-up Mapping Practices

- *Following switch-on, the timing of the first follow-up visit is typically scheduled between two to four weeks, irrespective of the age of the CI recipient. If closer monitoring is required, it is also recommended to do an earlier follow-up within 1 week.*
- *This timing can also vary based on the individual CI recipient's initial auditory responses, loudness tolerance, overall hearing progress, and prior hearing responses. However, it is similar across both adult and pediatric CI recipients.*

- *On average, four to five follow-up sessions may be required during the first quarter post CI switch-on. This number can vary based on individual patient progress, auditory adaptation and mapping-related challenges.*

According to the global survey by Vaerenberg et al. (2014b), follow-up during the first year after switch-on commonly consists of monthly sessions initially, followed by less frequent quarterly visits, resulting in an average of approximately seven follow-up sessions during the first post-activation year. This appears similar to the recommendation from the participants, of four to five follow-up visits within the first quarter alone, highlighting the increasing emphasis on intensive early follow-up during the initial stages of CI adaptation.

However, as mentioned before, the survey also notes that the number of visits can vary depending on the recipient's requirements. CIGI guideline (Vishwakarma & Mohandas, 2018) also highlighted the importance of consistent follow-up during the post-CI switch-on period, rather than prescribing a rigid number of follow-ups. Alternatively, the AAA guidelines (Messersmith et al., 2019) provide an approximate schedule for follow-up post-switch-on, which can also be tailored to individual CI recipients' conditions and requirements, along with considering the accessibility towards the CI care practising centres (Vaerenberg et al., 2014b).

Based on the expert's recommendations from the present study, the first follow-up visit may be scheduled within 2-4 weeks following the switch-on, with approximately four to five follow-up sessions recommended during the first quarter post activation, depending on the individual patient's needs. A typical follow-up schedule may include visits at 2 weeks, 4 weeks, 2 months, 3 months, 6 months and 12 months following switch-on, with annual follow-up thereafter to monitor map stability and auditory progress. The annual

follow-up sessions appear to be primarily intended for monitoring and ensuring that auditory performance remains stable, rather than for major map modifications, as the programming parameters generally become stable after the initial months following activation (Vaerenberg et al., 2014b; Vargas et al., 2012).

5.6 Bilateral and Bimodal CI Mapping

- *During bilateral CI mapping, it is important to consider loudness balancing across both ears to achieve comfortable, balanced binaural perception. Other than that, the overall mapping approach will be similar for each ear.*
- *For bimodal CI users, ensuring loudness balancing between the CI and hearing aid ears should be performed, and latency delay adjustments should also be considered to support balanced auditory perception.*

As per Litovsky et al. (2006), properly balanced bilateral CI users show improved binaural hearing and spatial perception, underscoring the importance of interaural balancing during the CI mapping procedure. Tyler et al. (2007) showed, in their study, the mapping of bilateral CI, with devices fitted separately for both ears and later matched for loudness. If there is any imbalance in the sounds between the ears, it is recommended to adjust the loudness levels. The AAA guidelines also suggested the same (Messersmith et al., 2019).

As in the Browning et al. (2020) study, wherein they highlighted the need for re-adjusting the CI or the hearing aid to match each other's acoustic stimulation, even with using the clinician's own clinical experience, the present study results also revealed the importance of achieving loudness balance across the ears without clearly portraying the exact procedure to be followed. Similar inconsistencies in bimodal aiding in the adult

population have also been reported before (Fielden & Kitterick, 2016; Siburt & Holmes, 2015). In the growing trend of placing CI in one ear by referring to the hearing aid in the opposite ear, a clear protocol should be introduced to overcome this inconsistency and utilise natural hearing as much as possible. One of the participants put forward the 'Teresa Ching's protocol' wherein the final loudness setting was done with the hearing aid on and set in NAL NL2 +/- 2 steps of high frequencies (Dorman et al., 2014). But there was no consensus on this, indicating a lack of uniformity in the fitting among the audiologists. Although the experts are united in achieving loudness balance across the ears, regardless of which hearing aid or fitting formula is used, the ultimate aim is to achieve balance.

5.7 Setting LSLs and USLs

- *Behavioural responses are mainly recommended to determine LSLs and USLs across the manufacturers, irrespective of age. Even if objective measures cannot be obtained to assist in setting the stimulation levels, the first line of approach will be behavioural methods.*
- *Patient feedback regarding loudness and comfort during live stimulation is also considered, especially in adult CI recipients.*
- *Furthermore, intraoperative measurements may also serve as an initial reference during programming.*

The methods for determining LSLs and USLs are given above as general. Previous literature already mentioned that the major changes that occur during each mapping session are for the LSLs and USLs (Vaerenberg et al., 2014a; Vaerenberg et al., 2014b). They also reported that both LSLs and USLs, determined mainly through behavioural means and objective measures, will be considered, with intra-operative and post-operative electrophysiological methods taken into account (Shapiro & Bradham, 2012; Vaerenberg

et al., 2014b). Most of the clinicians in Vaerenberg et al. (2014b) survey reported that they will go with the determination of stimulation levels only on a few electrodes, reportedly as few as three electrodes, and later it will be interpolated as a whole, which is similar to what was reported by the current study participants as well. It is also suggested that, unlike the current study's reports, it is possible to arrive only at the LSLs and position the USLs a few current levels above the LSLs (Vaerenberg et al., 2014b).

- *If using the loudness scaling chart to set loudness levels in a pediatric CI recipient, it is possible to directly correlate it with behavioural comfort levels, mostly using simple rating scales (e.g., 3 levels: soft, medium, and loud).*
- *In adult CI recipients, the loudness level selected is considered the comfortable level or the maximum comfortable loudness level. In most cases, stimulation levels can be set at or slightly below the USL (1-3 current levels) to ensure comfortable listening.*
- *Loudness levels are usually not measured across all the electrodes; it is applicable only when the assessment is performed during the initial switch-on, or on adult CI recipients, or when the CI recipient has become familiar with the hearing through CI, or when non-auditory stimulation is suspected.*

USLs are mainly set using three methods: loudness scaling, eSRT, and eCAP (Holder et al., 2023). For setting the USLs based on the loudness scaling charts, it is also required that the CI recipients participate and cooperate, and be able to understand them. As per Holder et al. (2023), the loudness level selected by the recipient for a specific USL current level is considered the 'comfortable' or 'most comfortable level', which correlates with the expert's opinion on the judgment of the level selected in the loudness scaling chart, especially for the adult CI recipients. Although the judgment on the loudness rating is

highly variable among individuals with hearing impairment (Geers et al., 2003). Similarly, this method is reported to be difficult to use with pediatric CI recipients, even though nearly half of the experts have agreed to use this method, which is a strange opinion.

But the trend clearly shows the importance of relying on behavioural responses as much as possible, as shown in Browning et al. (2020) and Vaerenberg et al. (2014b), and, although not directly assessed in Morris (2022), it also shows the same trend.

Methods for Determining LSLs and USLs in Cochlear Limited Devices

- *Objective measurements, such as eCAP/NRT responses, may also be commonly used to assist in determining these levels in pediatric CI recipients and non-cooperative clients, with LSLs/T levels often set above the measured eCAP thresholds and USLs/C levels typically set slightly below the measured eSRT threshold (3–5 clinical levels below).*
- *Population mean values may guide the determination of appropriate stimulation levels, in selected cases, such as when eCAP thresholds are not obtainable or when inner ear anomalies are present.*

Methods for Determining LSLs and USLs in MED-EL Devices

- *Objective measurements like eSRT responses may be recommended for setting USLs/Most Comfortable Levels (MCL), with MCL often set at the minimum level at which eSRT obtained and above the level of eCAP threshold.*
- *LSLs/Threshold (THR) levels may be locked at 8% of the MCL, while locking THR levels at 10% of the MCL may also be considered in selected cases.*
- *While doing mapping based on eCAP/ART, based on the ART threshold a base map will be created and then adjust with the behavioural response if reliable.*

Methods for Determining LSLs and USLs in Advanced Bionics Devices

- *Global adjustment in Live Speech mode followed by loudness balancing is preferred for measuring USLs/M levels in very young CI recipients, while single-channel (individual electrode) tone-burst stimulation is preferred in adults or older children, and Speech Burst stimulation across multiple channels may also be used as a default method.*
- *Objective measurements like eSRT responses may be recommended for setting USLs/M levels, with M level often set at the same level at which eSRT obtained.*
- *M levels may be estimated from eCAP/NRI/t-NRI responses by applying a positive offset of approximately 20–40 CU above the t-NRI threshold or by starting at t-NRI +10–15 CU followed by behavioral assessment and gradual adjustment of comfort levels as needed, while monitoring behavioral responses during increases in stimulation levels.*
- *LSLs/T level may be locked at 10% of the M level, generally be maintained during AB CI mapping.*

As in the previous studies, here also it is evident that the determination of LSLs and USLs across the manufacturers varies in terms of the technological aspect of the programming and the procedures to be followed (Browning et al., 2020; Morris,2022.). According to the Vaerenberg et al. (2014b) survey, the eCAP measures determine LSLs, and the eSRT determines USLs. The evoked potentials are mainly considered as a preliminary level, rather than performing as an ‘anchor point’ (Vaerenberg et al., 2014b). These levels are then shifted based on the recipient's response, according to their subjective appreciation of the sound elicited by electrical stimulation at these levels (Vaerenberg et al., 2014b).

Taking eSRT value for setting the MCL was recommended by the majority (70% in both pediatric and adult groups) for the MED-EL manufacturer; however, the previous survey by Vaerenberg et al. (2014b) got only 14% of the participants relying on this measure for setting USLs (Holder et al., 2023). To examine the relationship between the eSRT value and the USL, Holder et al. (2024) reported a correlation between the eSRT threshold and the MCL. The reason they gave was that MED-EL devices map 100 dB SPL input to the USLs. The lesser percentage of the participants recommending eSRT for setting USLs in Cochlear Limited (33-44%) and AB (33-50%) can be due to various reasons, the major one being, from the previous literature, the lack of clinician's confidence to judge the response or lack of practice, although recommendations already given for setting USLs in these manufacturers (approximately 15 clinical units lower for Cochlear and 11 clinical unit lower for AB). The lack of implementation of the recommendation into clinical practice can be seen from this; wherein for the Cochlear, it is recommended by a few of the experts from this study to set 3-5 clinical levels below the eSRT levels to set the USLs, unlike the 15 clinical units recommended in the literature. The strong correlation between MCL and eSRT may be one of the reasons it is used by the majority to set USLs.

Regarding the setting of LSLs, unlike the 'locking of threshold levels to a particular percentage of the comfort levels' in AB and MED-EL, Cochlear measures LSLs separately (Browning et al., 2020). According to Vaerenberg et al. (2014b) survey, majority of the participants of the current study selected 8% of the MCL to lock the THR level in MED-EL, rather than default 0 level to lock the threshold. The same trend difference was not seen in AB. In the literature, it was also mentioned that locking into 10% of M level was mentioned (Vaerenberg et al., 2014b). The systematic review by de Vos et al. (2018)

highlighted that, despite the widespread clinical use of eCAP measures as reported in the literature, the meta-analysis findings of pooled correlation remains only moderate to weak.

Even though studies have shown more importance to the eCAP based map among the objective measures, and more reliance on the same (Browning et al., 2020; Vaerenberg et al., 2014), there were studies showing the limitation of this eCAP measure (de Vos et al., 2018; van Eijl et al., 2017) and the importance of eSRT as the other objective measure for the determination of setting USLs, especially as given in the Holder et al. (2024) study. Therefore, although the eCAP measures are useful as a supportive tool in establishing initial maps, behavioural measures remain essential for accurate and individualised CI programming whenever appropriate (de Vos et al., 2018).

For Cochlear Limited, objective measures such as eCAP or eSRT, and electrode impedance telemetry are valuable during CI programming. Each has certain limitations and therefore cannot independently determine optimal stimulation levels. Thus van der Beek et al. (2014) further emphasised that even objective measures alone may not reliably predict behavioural stimulation levels; therefore, in difficult to fit cases, population mean values and predictive fitting profiles may serve as supportive starting points until individualised adjustments can be achieved.

Even though the values reported in the present study for the relationship between USLs and eSRT thresholds are not directly comparable to those in the Holder et al. (2024) study, a similar trend is evident. Similarly, the literature clearly shows that the eSRT measure is a better predictor of USL (Walkowiak et al., 2011), which is also incorporated in Indian clinical settings for predicting USLs. Unlike the literature, no single participant responded regarding eABR in special clinical conditions.

5.8 Approaches to Maintaining and Modifying Default CI parameters Across the Manufacturers

5.8.1 Default Parameters in Cochlear Limited Devices

- *Custom stimulation modes (e.g., MP1+2) may be used during electrode impedance measurements and during CI mapping.*
- *Detailed view windows may be preferred during CI mapping than Global View windows and Comfort View settings to facilitate efficient visualization and programming.*
- *Advanced NRT may be performed when eCAP responses are absent/ weak/inconsistent with the default pulse width, and it is also recommended to perform advanced NRT in cases with high electrode impedance and facial nerve stimulation.*
- *It is recommended to go with default settings for the speech coding strategy except in ANSD and inner ear anomaly cases.*
- *Unlike the default rate of stimulation, for individuals with a thin cochlear nerve and cases concerning battery consumption, it is recommended to go with a lower stimulation rate.*
- *And if not getting benefit with the pulse width and rate change, in inner ear anomaly cases, it is recommended to go with the change in the default maxima setting.*
- *Default pulse width settings may generally be maintained during CI mapping; however, pulse width adjustments may be considered in cases of reduced dynamic range, absent eCAP responses, inner ear anomalies, non-auditory stimulation, or other compliance-related issues.*
- *Default volume adjustment settings should generally be maintained except in inner ear anomaly cases.*

- *Default loudness growth settings and volume and sensitivity settings will not change in any circumstances.*
- *Default frequency table power settings will be maintained in all cases except partial insertion cases.*
- *Based on the listening needs, the following pre-processing features can be used for pediatric CI recipients: SCAN>SCAN-2>SNR-NR>FF>ADRO>WNR.*
- *Similarly, for adult recipients, it is recommended in the following order SCAN=SCAN 2=FF>ADRO=WNR>SNR-NR>ASC.*

The cochlear reference guide explains that the default MP1+2 mode delivers the lowest electrode impedance because current flows simultaneously between the active intracochlear electrode and both extra-cochlear electrodes. The experts are recommending that this may be due to its flexibility and access to change the higher stimulation rate. The study by Shapiro and Bradham (2012) further supports monopolar stimulation as the preferred mode, given consistent threshold levels across the array, which facilitate interpolation. Detailed view windows may be preferred by participants, as they facilitate better visualisation of individual electrodes and map parameters, thereby allowing more precise, individualised programming adjustments.

In cases of high electrode impedance or compliance issues, it is recommended to widen the pulse width or adjust the stimulation mode to bring the channel back into compliance. Thus, Advanced NRT should be considered in challenging cases, as default NRT may not capture responses when electrode impedances are high or when facial nerve stimulation complicates interpretation. It is recommended to retain the default speech coding strategy (Morris, 2022.; Shapiro & Bradham, 2012) unless clinically indicated, as

in cases of ANSD and inner ear anomalies, where modifications are required based on individual needs.

Similarly, default stimulation rates are generally maintained, other than for recipients with a thin cochlear nerve, and battery consumption becomes a concern. Shapiro & Bradham (2012) explained that stimulation rate influences temporal coding, neural responsiveness, and power consumption to justify this. Additionally, Morris (2022) reported that clinicians occasionally modified stimulation-related parameters depending on individual patient requirements and listening performances.

Default pulse width settings are generally maintained during routine CI mapping. However, pulse-width adjustments may be considered in cases involving reduced dynamic range, absent eCAP responses, inner-ear anomalies, non-auditory stimulation, or voltage compliance issues. Shapiro & Bradham (2012) explained that this pulse width directly affects charge delivery and loudness perception, and therefore increasing pulse width may help achieve sufficient stimulation while reducing excessive current requirements. In cases of partial electrode insertion or electrode migration, it is recommended to use only the electrodes inside the cochlea for electrical stimulation and to explicitly discourage the use of common ground stimulation mode other than MP mode.

Shapiro and Bradham (2012) also reported that maxima adjustments may sometimes improve auditory performance in recipients with atypical neural survival or altered cochlear anatomy when default settings provide limited benefit, which correlates with the participant's view on changing the default maxima in cases of inner ear anomalies where sufficient benefit is not achieved with modifications in pulse width and stimulation rate.

For the Cochlear devices, the most frequently modified device parameter was the Auto-sensitivity feature, which was commonly deactivated, as per the Vaerenberg et al. (2014b) survey. In addition, cross-sectional data indicated that parameters such as channel rate, number of maxima, and pulse width were altered in approximately 5-8% of cases.

Coming to the pre-processing strategies, the survey ranking prioritises automatic environment adaptations first (SCAN/ SCAN 2), followed by Noise reduction (SNR-NR), directional enhancement (FF), dynamic range optimisation (ADRO), and finally suppression (WNR), reflecting the greater need for automisation in children. For adults, SCAN/SCAN 2/FF gives similar priorities because adults can actively control these through the Nucleus smart app and can benefit from both automatic and user-controlled noise management. The literature provided information on the effects of these strategies on speech perception, indicating that combining strategies is more effective than using them alone (Gifford et al., 2011).

5.8.2 Default parameters in MED-EL Devices

- *If by any chance the electrode needs to be disabled, then it is required to manipulate the default settings for the frequency bands.*
- *AGC sensitivity setting can be changed from the default 75% to 100% if clinically indicated.*
- *Unless it is getting higher MapLaw values with inadequate loudness and speech clarity, it is always recommended to go with the default setting.*
- *Based on the listening requirement, the default setting for microphone directionality can be manipulated.*

- *Default settings for the speech coding strategy, AGC compression ratio, volume mode, and wind noise reduction will generally be maintained.*
- *Adaptive Directionality, Ambient Noise Reduction/ANR, and ASM front-end preprocessing features can be enabled for pediatric and adult CI recipients.*

MED-EL programming protocols also emphasised, individualised adjustments only when clinically indicated, rather than routine modification of all parameters (Morris, 2022; Wolfe & Schafer, 2015). To maintain appropriate frequency-place mapping, it is important to manipulate the frequency allocation to redistribute spectral information (Wolfe & Schafer, 2015). Similarly, AGC sensitivity changed from the default 75% to 100%, allowing greater access to softer environmental and speech signals (Shapiro & Bradham, 2012; Vaerenberg et al., 2014b; Wolfe & Schafer, 2015). As in Vaerenberg et al. (2014b) survey, MapLaw values are manipulated in cases with inadequate loudness growth or poor speech clarity.

Studies on directional microphone technologies and beamforming have also demonstrated significant improvements in speech perception in noise. Honeder et al. (2018) reported that both fixed and adaptive beamforming significantly improved speech reception thresholds compared to omnidirectional microphone settings, with adaptive beamforming providing greater benefit. Wimmer et al. (2016) also found that the effectiveness of microphone modes depends upon the spatial location of noise, emphasising the value of flexible microphone settings in different listening situations.

5.8.3 Default parameters in Advanced Bionics Devices

- *Pulse Width adjustments from APW I to APW II or manual modifications were mainly considered in cases approaching compliance limits due to high thresholds or elevated electrode impedance values.*
- *Likewise, increasing the IDR to 70–80 dB in experienced users to provide a broader acoustic range and enhance music perception can be considered, while continuing to maintain 60 dB IDR for newly implanted users.*
- *Other than these, the default settings for the speech coding strategy, gain for the channels, volume max and min, microphone sensitivity, audio mixing, microphone mode, filter setting, and AGC 2-dual loop will generally be maintained.*
- *Based on the listening needs, the following pre-processing features can be used for pediatric CI recipients: Ultrazoom>clear voice = T-mic 2 = zoom control.*
- *Similarly, for adults, it is recommended as T-mic 2> clear voice> Ultrazoom=zoom control.*

Ultrazoom is often preferred in children because beamforming significantly improves speech perception in noise, while ClearVoice enhances speech understanding in steady and multi-talker noise situations. T-mic 2 provides better speech perception in noise by utilising the natural pinna effect, and studies have demonstrated significant improvements in speech perception in noise with all these strategies (Mosnier et al., 2017).

Overall, default mapping parameters are rarely changed, unlike LSLs and USLs (Vaerenberg et al., 2014b). The clinician's decision to use the default setting has already been discussed in several studies (Morris, 2022; Wathour et al., 2021), unless clinically indicated. According to Wathour et al. (2021), the default settings of the CI mapping

parameters, including programming strategies, mode of stimulation, loudness growth, and similar parameters across manufacturers, are not recommended to be manipulated. Similar trends have been shown in Morris (2022), where the preference of the Indian Audiologist over the default mapping parameters across the manufacturers has been clearly depicted, which entirely justifies the present study results. Very rarely, or only in clinically concerning cases, manufacturers have recommended deviation from the default settings. This aligns with the Browning et al. (2020) study of the American population and the Vaerenberg et al. (2014b) global survey.

5.9 Indicators of CI Map Stability and Optimization

- *A CI map is considered to be stable or optimized when the aided thresholds and speech perception performance are satisfactory, and also when the CI recipient provide consistent feedback regarding the quality of sound and loudness.*
- *The absence of further of complaints related to the loudness discomfort or unclear sound perception can also be considered as a stabilized map.*
- *The judgement of the clinician based on long-term follow-up experience and overall patient progress may contribute to determine whether the map is stable or optimized.*
- *In other words, 'stabilized map' can also be defined as when there are no significant fluctuations in electrode impedance levels, voltage measures, and other findings across sessions.*
- *In clinical practice, LSLs and USLs coming within a particular range across two or more visits, with sufficient dynamic range, are also recommended as a stabilised map.*

- *A CI map is considered to be stable or optimized when the aided thresholds and speech perception performance are satisfactory, and also when the CI recipient provides consistent feedback regarding the quality of sound and loudness.*

Brummer and Turner (1977) highlighted that in the case of both pediatric and adult CI recipients, there will be a plateau of the USLs achieved by around 1 year following the switch-on, wherein there will be a significant increase in USLs due to acclimatisation to the electrical stimulation and an increase in tolerance towards the loud sounds. Vaerenberg et al. (2014b) survey suggested that an intensive schedule of consecutive mapping sessions will allow the recipient to achieve a stable map faster, and accessibility to CI mapping procedures can also be considered a practical need for attaining stable maps as early as possible.

5.10 Timing of ALD Recommendation in CI Recipients

- *The timing for recommending ALDs for pediatric CI recipients varies depending on the child's auditory progress, listening needs and clinical judgment. When the recipient needs additional listening support, ALDs can recommend them at the time of initial switch-on or during the first follow-up session.*
- *Similarly, for adult CI recipients, the recommendations for ALDs vary depending on communication needs, listening difficulties, and clinical judgement.*

There are no studies or standardized guidelines showing the exact timing to recommend the ALDs to the CI recipient, unlike hearing aids, although it is acknowledged that the timing will depend mainly on the individual CI recipient's need and progress, as the majority of the participants agreed, which is mentioned in the previous literature (Ec & Lm, 2006; Wolfe et al., 2015).

5.11 Consistency in CI Mapping

- *When the mapping procedure is managed by more than one clinician within a centre, to overcome problems with consistency in mapping, it is recommended to follow a standardised centre-specific protocol, shared patient mapping records, and periodic team reviews or case discussions among the audiologists involved in CI mapping.*

The American Academy of Audiology CI practice guidelines highlighted the importance of coordinated CI team functioning (Messersmith et al., 2019), and evidence for the varied clinical practice to both between and within centres (Wathour et al., 2021) in CI mapping procedure, showing the importance of this statement, which puts forward an idea for ensuring the consistency in the CI mapping at least within a centre. The global survey by Vaerenberg et al. (2014b) also showed this variability across centres in CI mapping procedures, most importantly within centres, between clinicians, and between different categories of CI recipients (especially pediatric vs adult CI recipients). Overall, it is also evident that in several areas there were no major differences in the CI mapping procedures across the age, including the CI programming technique (Fielden & Kitterick, 2016). The protocol derived from the expert's responses, justified by the literature, is provided below, in Figure 5.1.

Table 5.1

Comprehensive cochlear implant mapping protocol

COCHLEAR IMPLANT MAPPING PROTOCOL

This protocol provides a structured, comprehensive and clinically practical framework for CI mapping, with particular relevance for clinicians new to the CI field. This guideline is not a rigid rule book; it is adaptable based on the recipient's age, auditory responses, clinical conditions, device manufacturers and models.

STEP 1: CONFIRM READINESS FOR SWITCH-ON

Before proceeding with activation, all four readiness domains must be assessed. If any concern is identified, the clinician should refer or postpone activation.

A. Surgical site	**B. Medical clearance**	**C. Recipient readiness**	**D. Clinical records**
• Redness or swelling • Signs of infection • Wound tenderness • Poor wound healing	• Surgeon approval confirmed • Post-operative status reviewed • No unresolved complications	• Fever or active illness • Adequate attention span • Behavioural cooperation • Emotional state stable	• Intraoperative electrode impedance • Intraoperative eCAP / eSRT • Imaging (X-ray / CT / MRI) • Presence of anomalies • Surgical notes

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

All criteria met?	**→ YES: Proceed to Step 2**	**→ NO: Refer / Postpone activation**

STEP 2: DETERMINE SWITCH-ON TIMING

Traditional switch-on	Early switch-on
• 10 – 30 days post-surgery • Standard wound healing window • Most common approach	• Within 24 hours – 10 days • Adequate wound healing confirmed • Medical clearance available • Stable post-operative condition • Family preference or accessibility needs exist

Note: Early switch-on generally does not negatively affect outcomes. It may improve psychological reassurance for the family and facilitate earlier auditory rehabilitation

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

STEP 3: INITIAL DEVICE CONNECTION

Hardware verification

- Connect processor to programming software
- Verify software communication
- Confirm processor compatibility
- Check battery status

Signal integrity

- Verify coil retention and magnet strength
- Ensure stable telemetry connection
- Check for intermittent dropouts

STEP 4: ELECTRODE IMPEDANCE MEASUREMENT

Always begin with full electrode impedance testing. This provides foundational information about electrode status and helps identify any abnormalities that may affect programming decisions.

Run impedance measurement	**→ Normal: proceed with mapping**	**→ Abnormal: troubleshoot first**

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

First-line checks	Persistent abnormalities	Troubleshooting tools	Deactivation criteria
• Re-run electrode impedance • Re-check coil placement • Re-check magnet strength • Consider URTI / ear pain • Consider temporary tissue changes	• Open circuit electrode • Short circuit electrode • Extracochlear electrode • High electrode impedance values • Compliance problems • Abnormal adjacent values	• Electrode conditioning • Pulse width adjustments • Compliance adjustments • Re-measure telemetry • Electrode deactivation if needed	• Persistent abnormal electrode impedance • Confirmed extracochlear placement • Non-auditory stimulation • Facial nerve stimulation • Poor objective responses • Software warnings

STEP 5: OBJECTIVE MEASUREMENTS

Available objective measures	Primary use cases
• eCAP / NRT / ART / NRI • eSRT (electrically evoked stapedius reflex) • Electrode impedance telemetry • Intraoperative eCAP / eSRT findings	• Initial map guidance and estimating stimulation levels • Support for difficult-to-test recipients • Young children and non-cooperative patients • Cross-check and validation of behavioural levels

IMPORTANT: Objective measures alone are NOT sufficient to produce a complete and optimised map. Behavioural responses remain the primary source of information whenever obtainable. Objective data serves a supportive, not definitive, role.

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

STEP 6: DETERMINE STIMULATION LEVELS

The stimulation levels are primarily determined using behavioural methods, supplemented by objective measures, and also not all electrodes will undergo measurements; most of the time, an interpolated value across the electrode to be taken.

LSL / T-Level Determination

Primary methods	Supportive methods
• Behavioural observation • Conditioned response techniques • Loudness scaling • Patient verbal feedback	• eCAP-derived estimates • Population mean values • Intraoperative findings (supportive only)

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

USL / MCL / C-Level Determination

Primary methods	Supportive methods
• Loudness judgement • Comfort scaling (e.g., 1-10 scale) • Live speech stimulation feedback • Behavioural feedback responses	eSRT for USLs estimation: Adult CI recipients • Cochlear (PW 25 μs): C-levels ≈ 15 CL below eSRT • Cochlear (PW 37 μs): C-levels ≈ 13 CL below eSRT • Advanced Bionics: M-levels ≈ 11 CU below eSRT • MED-EL: MCL ≈ at eSRT level (±0.1 qu) -Holder et al.,2024 eSRT for USLs estimation: Pediatric CI recipients • Cochlear (irrespective of PW): C-levels ≈10-15 CL below eSRT • Advanced Bionics: eSRT within 5–10% of M-level • MED-EL: MCL ≈ at eSRT level -Wolfe & Schafer., 2015 eCAP-based prediction Population mean values (Cochlear Limited)

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

Recipient-Specific Approaches

Pediatric recipients	Adult recipients
• Simple loudness scaling: soft / medium / loud • Watch for eye widening or smiling • Monitor for startle responses • Device removal = too loud • Crying or clear distress signals	• Comfort level judgement (numeric scale) • Loudness balancing across electrodes • Speech clarity feedback in quiet and noise • Program slightly below uncomfortable level

STEP 7: MANUFACTURER-SPECIFIC MAPPING

Default settings are generally maintained for all manufacturers. Modifications should only be made when clinically indicated. The following guidance reflects current best-practice parameters

A. Cochlear Limited	
General principle	Maintain default settings; modify only when clinically indicated
Common adjustments	Pulse width, stimulation rate, maxima, frequency allocation, volume/sensitivity, compliance adjustments
When to modify	Inner ear anomalies, thin cochlear nerve, reduced dynamic range, absent eCAP, battery consumption concerns, facial nerve stimulation, compliance issues
Pediatric preprocessing priority	SCAN > SCAN-2 > SNR-NR > FF > ADRO > WNR
Adult preprocessing priority	SCAN = SCAN-2 = FF > ADRO = WNR > SNR-NR > ASC

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

B. Med-El	
General principle	Maintain default parameters unless clinically required to change
Common adjustments	Frequency allocation, AGC sensitivity, MapLaw, directionality, MCL adjustments
THR locking	Usually 8% of MCL; 10% in selected cases
Objective guidance	eSRT for MCL; ART / eCAP as supportive measures
Preprocessing features	Adaptive Directionality, ANR, ASM, WNR — improve SNR, reduce listening effort, enhance comfort

C. Advanced Bionics	
General principle	Default settings usually maintained
Common adjustments	APW I to APW II, manual pulse width changes, IDR expansion (experienced users)
When to modify	Compliance issues, high thresholds, elevated electrode impedance, music perception concerns
Paediatric preprocessing priority	UltraZoom > ClearVoice = T-Mic 2 = ZoomControl
Adult preprocessing priority	T-Mic 2 > ClearVoice > UltraZoom = ZoomControl

STEP 8: PROGRESSIVE MAP DECISION

Progressive maps are not required for all recipients. Their use should be guided by the following factors:

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

Recipient factors	**Clinical factors**	**Access factors**	**Who may not need**
• Age of recipient • Auditory adaptation rate • Loudness tolerance profile	• Behavioural reliability of responses • Clinician judgement • History of sensitivity	• Follow-up appointment availability • Distance from centre • Caregiver support	• Experienced adult recipients • Reliable behavioural responders • Stable post-reimplantation cases

STEP 9: FOLLOW-UP MAPPING SCHEDULE

The first follow-up appointment is usually scheduled 2–4 weeks post switch-on, or earlier if clinical concerns arise. The schedule below reflects a typical evidence-informed follow-up pathway.

2 weeks	Electrode impedance check, initial stimulation level verification, device adaptation review
4 weeks	Re-measure LSL/USL, early speech perception assessment, and caregiver feedback
2 months	Aided threshold measurement, loudness balancing, and counselling update
3 months	Comprehensive speech perception testing, full troubleshooting, and map refinement
6 months	Comprehensive review, map optimisation, aided thresholds, and rehabilitation progress
12 months	Annual review, aided thresholds, speech perception, and long-term counselling
Annually	Ongoing long-term monitoring, device integrity review, and ALD consideration

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

At Each Follow-Up Appointment

Measurement	**Perception**	**Technical**	**Support**
• Electrode impedance check • Re-measure LSL / USL • Aided threshold testing	• Speech perception testing • Loudness balancing • Binaural assessment (if applicable)	• Troubleshooting any issues • Device and coil integrity • Software review	• Counselling update • Rehabilitation planning

STEP 10: BILATERAL / BIMODAL MANAGEMENT

Bilateral CI recipients	**Bimodal users (CI + hearing aid)**
• Loudness balancing across both ears • A similar mapping procedure applied to each ear • Assessment of binaural comfort • Consider sequential versus simultaneous fitting approach, that means program each ear separately than doing simultaneously. Then later do loudness balancing across the ears. • Monitor binaural integration over time	• Balance CI and hearing aid loudness levels • Consider and adjust for latency differences between devices • Optimise hearing aid fitting (NAL-NL2) • Assess binaural integration and speech-in-noise benefit • Monitor for asymmetric adaptation over time

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

STEP 11: DETERMINE MAP STABILITY

Stability criteria	Expected stabilisation timeline
• Stable electrode impedance values across visits • Consistent aided thresholds • Good and stable speech perception scores • Adequate dynamic range maintained • Stable loudness growth function • Minimal patient or caregiver complaints • Minimal map changes needed across consecutive visits	• Initial rapid changes: first 1–3 months post-activation • Gradual stabilisation: 3–12 months • Plateau typically reached by approximately 1 year • Adult-onset deafness recipients may stabilise faster • Paediatric recipients or those with anomalies may require longer

Map considered stable?	**→ YES: Transition to annual review**	**→ NO: Continue closer follow-up schedule**

Table 5.1 (Continued)

Comprehensive cochlear implant mapping protocol

STEP 12: LONG-TERM MANAGEMENT

Long-term clinical goals	Clinical consistency and governance
• Maintain and monitor auditory progress • Longitudinal speech perception monitoring • Monitor device and electrode integrity • Ensure ongoing listening comfort • Consider assistive listening devices (ALDs) • Continue annual review appointments	• Shared mapping records across multi-clinician teams • Centre-specific protocol adherence • Multi-disciplinary team discussion for complex cases • Periodic protocol review and update meetings • Continuing professional development for all clinicians

The end goal of this entire protocol is an optimised and stable CI map that provides the recipient with consistent, comfortable auditory access across all real-world listening environments.

Chapter VI

Summary and Conclusion

The success of CI lies in improved speech recognition, thereby reducing the overall communication barrier among individuals with hearing impairment. Establishing a standardised CI mapping protocol based on expert consensus can reduce variability in clinical practice, improve patient outcomes, and ensure consistent service delivery across manufacturers and regions.

The present study aimed to develop evidence-based and contextually useful guideline for CI mapping procedures to be used by audiologists in India. The study reviewed the current global and Indian CI mapping practices, document the approaches followed by Indian audiologists, and develop standardised guideline based on expert's consensus. To achieve these, a survey-based consensus approach was followed. A comprehensive review of literature on CI mapping practices was conducted, and based on that a questionnaire comprising of general CI mapping practices and manufacturer specific programming procedures was developed and reviewed by experts in the field, before publishing it, as a part of content validation. The questionnaire was distributed to experienced audiologists across India, and responses from 20 participants were collected. Data collection was terminated upon achieving data saturation. The responses were analysed using frequency and percentage analysis, and consensus statements were generated based on areas of agreement among participants. Later, these statements were used to generate the guideline for CI mapping procedures to be used by audiologists. The findings of the study are summarised below as conclusions:

- Prior to switch-on, readiness should be confirmed by assessing wound healing, absence of infection, medical clearance, and review of intraoperative and radiological findings.

Initial activation is generally carried out within 10-30 days post-surgery for both pediatric and adult CI recipients, although earlier activation may be considered.

- Electrode impedance measurements should be performed at every mapping session, with electrode deactivation considered only when persistent abnormalities are identified. The use of progressive maps should be individualized, while common switch-on challenges include parental anxiety, unreliable behavioral response and intolerance to initial stimulation levels.
- The first follow-up is generally recommended within 2-4 weeks after switch-on, with 3-5 follow-up sessions during the first three months. For bilateral and bimodal users, loudness balancing is important to achieve balanced auditory perception, with latency adjustments considered, when necessary, in bimodal fittings.
- Behavioural responses were the primary method recommended for determining LSLs and USLs across all manufacturers and age groups, while objective measures such as eCAP and eSRT served as supportive tools, particularly in pediatric and difficult to fit cases. Manufacturer specific recommendations were also identified regarding stimulation level setting, programming parameters, and pre-processing strategies for Cochlear Limited, MED-EL and Advanced Bionics devices.
- The present study represents a consensus-driven effort to address the CI mapping procedure in India. The 66 consensus statements collectively form a structured, flexible framework rather than a rigid rulebook, allowing clinicians to adapt to individual patient contexts while maintaining a consistent standard of care. The current study provides a structured outline of the CI mapping procedure, thereby serving as a practical guide for audiologists and clinicians. This guideline is anticipated to be particularly beneficial for novice practitioners and early-career professionals by supporting clinical decision-making and facilitating the adoption of standardized mapping practices.

6.1 Limitations of the Study

- The use of voluntary response sampling may have introduced participation bias, as professionals who participated could have been more interested, experienced, or engaged in CI mapping and sharing of information compared to the wider CI community
- Participants did not have equal clinical experience across the manufacturers, which may have affected the representativeness of the manufacturer-specific recommendation.

6.2 Implication of the Study

- The consensus statements provide structured guidance for both inexperienced and experts in the CI mapping-related field, supporting more consistent and evidence-aligned programming practices from switch-on to long-term follow-up.
- The framework may help reduce uncertainty in early programming decisions, encourage reflective clinical practices, and minimise unnecessary parameter modifications.
- The findings also have implications for audiology training programs in India and may serve as a structured competency framework for CI mapping training.

6.3 Future Directions of the Study

- Future prospective studies are needed to evaluate whether the use of these consensus-based protocols improves clinical outcomes such as speech perception, aided hearing performance, quality of life and recipient or parent satisfaction.

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APPENDIX

Questionnaire used for Item Generation: CI Mapping Practices — Expert Survey

Dear Participant,

Thank you for agreeing to take part in this study. The purpose of this round is to gather your professional insights on Cochlear Implant (CI) mapping and outcome assessment practices. Your insights will truly help shape practical guidelines for CI mapping and outcome protocols in the Indian context. We genuinely request you to share your thoughts honestly and openly. There are no 'right' or 'wrong' answers — your real experiences are what make this valuable. Your input will go a long way in supporting and guiding the next generation of budding audiologists.

This form starts with Demographic details of the participant followed by a set of general questions in Section 1 covering key areas such as switch-on procedures and follow-up mapping. In Section 2 you will be asked to indicate which CI company or companies you have experience with. Based on your selection, you will be directed to the relevant section for each company (Cochlear, MED-EL, or Advanced Bionics) to provide your detailed responses. You may share information for as many companies as you have worked with.

While the options below cover commonly reported responses, there may be additional perspectives or details. Please use the "Other" option to specify any information not listed.

Estimated time: 15–20 minutes. *Your responses will remain confidential and used only for academic purposes.*

* Indicates required question

Demographic Details

Q1. Name

Q2. Please provide your email ID

Q3. Phone number

Q4. What is your highest qualification?

○ BASLP / B.Sc. (Speech and Hearing)

○ MASLP / M.Sc. (Audiology)

○ Ph.D. (Audiology)

○ Other: _____

Q5. Current workplace setting

○ Government hospital

○ Private hospital

○ Private clinic

○ Academic institution

○ Other: _____

Q6. Are you actively involved in CI services — such as evaluation, switch-on, mapping, follow-up or outcome measures? *

○ Yes

○ No (Please end the form here)

Q7. Please indicate your level of experience with each CI manufacturer (number of CI cases handled with each company) *Check all that apply*

CI Manufacturer	**1–25**	**26–50**	**51–75**	**75–100**	**>100**
Cochlear	☐	☐	☐	☐	☐
MED-EL	☐	☐	☐	☐	☐
Advanced Bionics	☐	☐	☐	☐	☐

Q8. How many years of professional experience do you have in CI-related work?

○ Less than 5 years

○ 5–10 years

○ More than 10 years

Q9. Please indicate your current professional role (e.g., clinician, academic, researcher, trainer)

_____

Q10. What is the primary population you work with?

○ Pediatric

○ Adult

○ Both pediatric and adult

Q11. Which region of India do you practice in?

_____

Q12. The major objective of this study is to generate a flexible guideline based on statements from experts in the field, helpful for professionals who are new to various procedures related to CI. Are you willing to participate in all rounds? *

○ Yes

○ No

SECTION 1: Switch-on and Follow-up Mapping (General Questions)

This section contains general questions related to CI mapping procedures. Kindly respond based on your professional experience, and feel free to add any opinions or suggestions in the designated space.

Q13. As per your recommendation, after how many days following CI surgery should the activation/switch-on be performed? Please mention the number of days separately for adults and children. *****

Adults:

_____

Children:

_____

Q14. Before connecting the implant to the software during switch-on, which of the following details do you refer to in order to confirm readiness for switch-on? *
Select all that apply.

☐ CT/MRI (Pre-implant)

☐ Review intraoperative electrode impedance

☐ Intraoperative eCAP / Stapedial Reflex report

☐ Verify X-ray or imaging reports for electrode placement

☐ Inspect surgical site for redness, swelling, or infection

☐ Ensure wound healing is adequate

☐ Confirm medical clearance or surgeon's approval for switch-on

Q15. Under what circumstances, if any, would you decide to deactivate (switch off) an electrode following the electrode impedance check? *

○ I usually keep the default electrode impedance settings

○ I will manually deactivate the electrode in several cases (Please mention such conditions below.)

○ Other: _____

Q16. When you observe concerning electrode impedance patterns (e.g., zig-zag pattern across electrodes, single-electrode spikes, or abrupt value changes) what steps do you typically take? *

○ I consider all values acceptable if within the manufacturer's acceptable range

○ I will do troubleshooting and re-run electrode impedance

○ Other: _____

Q17. If you selected the second option in the previous question, please briefly describe the troubleshooting steps you recommend for each concerning electrode impedance pattern. *

_____

Q18. Are there any differences in the troubleshooting steps used for concerning electrode impedance patterns in adults compared to children? Briefly describe (2–3 sentences).

_____

Q19. Do you always use progressive maps during the switch-on session for children and adults, or are there situations where this approach does not apply? * *Select all that apply.*

☐ Yes, I always use progressive maps during the switch-on session for all recipients irrespective of age

☐ I decide case by case, depending on age, etiology, or device parameters. (Please specify in the 'Other' field below.)

☐ Other: _____

Q20. What challenges do you frequently encounter during the initial switch-on session for both children and adults? * *Select all that apply.*

☐ Difficulty obtaining reliable behavioral responses from children or non-cooperative clients

☐ Poor electrode impedance or telemetry readings

☐ Facial stimulation or non-auditory sensations during mapping

☐ Discomfort or intolerance to initial stimulation levels

☐ Parental anxiety or limited understanding during the session

☐ Software or connectivity issues with the programming system

☐ Variability between intraoperative and postoperative responses

☐ Other: _____

Q21. When do you usually perform audiometric testing in relation to the switch-on session? * *Select all that apply.*

☐ I recommend PTA before switch-on to assess residual hearing

☐ I perform PTA immediately after switch-on in the same session for all recipients

☐ Audiometry is not routinely performed around switch-on unless clinically indicated

☐ I perform PTA only for adults during switch-on

☐ I perform PTA only for specific cases (Please specify the clinical situations in the 'Other' field.)

☐ Other: _____

Q22. After the initial switch-on session, when do you recommend the first follow-up visit for the recipient? * *Select all that apply.*

☐ Within 1 week after switch-on

☐ Within 2–4 weeks after switch-on

☐ After 1 month

☐ Based on institutional or manufacturer protocol

☐ Depends on the patient's tolerance and initial response. (Please describe how you make this decision in the 'Other' field.)

☐ Other: _____

Q23. Does the timing of the first follow-up visit differ between adult and pediatric recipients? *

○ No

○ Yes — (Please specify the typical duration followed for each group below.)

○ Other: _____

Q24. According to your clinical practice, how do you define the loudness level selected by the Pediatric CI recipient on the loudness scaling chart? *

Select all that apply.

☐ I do not use loudness scaling charts while mapping pediatric CI recipients

☐ If you use it, please mention how you interpret and use this information to determine the USL/C/M level in the 'Other' field.

☐ Other: _____

Q25. According to your clinical practice, how do you define the loudness level selected by the Adult CI recipient on the loudness scaling chart? *

Select all that apply.

☐ I do not use loudness scaling charts while mapping adult CI recipients

☐ If you use it, please mention how you interpret and use this information to determine the USL/C/M level in the 'Other' field.

☐ Other: _____

Q26. When do you measure the loudness level across individual electrodes? Please specify the circumstances.

_____

Q27. For bilateral users, do you follow a different mapping approach compared to unilateral users? If yes, what are the key considerations or adjustments you make? (Briefly explain in 2–3 sentences.) *

_____

Q28. For bimodal users, do you follow a different mapping approach compared to unilateral users? If yes, what are the key considerations or adjustments you make? (Briefly explain in 2–3 sentences.) *

_____

Q29. After switch-on, how many follow-up sessions are needed in the first quarter? *

Number of sessions:

_____

Q30. How do you determine when a map is considered stable or 'optimized'? * *Select all that apply.*

☐ Lower Stimulation Level (LSL) & Upper Stimulation Level (USL) values coming within a particular range across two or more visits

☐ Consistent patient feedback on sound quality and loudness

☐ Satisfactory aided thresholds or speech perception results

☐ No further complaints about loudness or clarity

☐ Objective measures (e.g., eCAP, eSRT) remain consistent

☐ Clinician's judgment based on long-term follow-up experience

Q31. Briefly describe the parameters you rely on to determine map stability. (e.g., A map is said to be stable if the USL is not going beyond '_' levels from the previous map USL level — if you recommend anything like this, please mention.)

_____

Q32. How frequently do you check electrode impedance after the initial stabilization period? * *Select all that apply.*

☐ At every follow-up mapping session

☐ Only if there are patient complaints or performance changes

Q33. When will you recommend giving Assistive Listening Devices (e.g., Roger Direct, Wireless Mini Microphone 2+) for CI recipients? *

Check all that apply.

Population	**Switch-on**	**First follow-up**	**After 3 months of switch-on**	**After 6 months of switch-on**	**After 1 year**
Pediatric	☐	☐	☐	☐	☐
Adult	☐	☐	☐	☐	☐

Q34. Are you the sole audiologist for mapping in your center? *

○ Yes

○ No

Q35. If 'No' in the above question, how do you ensure consistency in mapping across different audiologists in your team? Please select only one option. *

○ Follow a standardized centre protocol for mapping

○ Maintain shared patient mapping records for team reference

○ Conduct periodic team reviews or case discussions

○ Use manufacturer or software templates for standardization

○ Other: _____

SECTION 2: Manufacturer-Specific Information

This section will focus on manufacturer-specific mapping practices. Kindly respond based on your professional experience, and feel free to add any opinions or suggestions in the designated space.

If you have experience with more than one manufacturer, **you have the opportunity to select that manufacturer when the question appears again.** This will help ensure that you receive the appropriate set of questions relevant to your experience.

After answering for all the manufacturers you have experience with, choose the fourth option and submit the form.

COCHLEAR

Kindly fill all the required details. This will take approximately 5–10 minutes.

Q1. While performing electrode impedance measurements, which modes of stimulation do you prefer the most? *

☐ Custom mode (e.g., MP1+2)

☐ Mode selection depends on clinical indication or patient condition (Please specify the condition and preferred mode below.)

☐ Other: _____

Q2. Among the following, which window would you recommend for mapping in the current Custom Sound 7.0 software?

Acoustic	Global	Comfort	Thresholds	Other

Q3. Do you recommend using the population mean MAP as the starting MAP during CI switch-on? *

○ No

○ Yes — (Please specify the situation when you recommend population mean MAP during switch-on.)

○ Other: _____

Q4. When do you recommend performing Advanced NRT in Custom Sound EP software, particularly in relation to pulse width adjustments (e.g., 25 µs or 37 µs)? * *Select all that apply.*

☐ I perform it when eCAP responses are absent at default pulse width

☐ I try both pulse widths (25 µs and 37 µs) when eCAP responses are weak or inconsistent or when artefact obscures the eCAP waveform

☐ I adjust pulse width based on intraoperative eCAP results

☐ I use a specific pulse width depending on the model of the implant

☐ I change pulse width for patients with high electrode impedance or facial stimulation issues

Q5. Which methods do you commonly recommend to determine the LSL (T levels) and USL (C levels) during the switch-on session for Cochlear recipients? * *Select all methods or approaches you commonly use.*

Methods	Pediatric	Adult
eCAP / NRT responses	☐	☐
eSRT Response	☐	☐
Behavioral Response	☐	☐
Patient feedback on loudness & comfort during live stimulation	☐	☐
Comparing with intra-op measurements for initial reference	☐	☐
Based on previous experience or clinic protocol	☐	☐
Relying primarily on manufacturer-recommended default mapping templates	☐	☐
I use population mean	☐	☐

Q6. Do you recommend eCAP/NRT for setting the levels? *

○ No

○ Yes — (Please describe how you relate these responses to T and C levels, e.g., setting C levels '_' Current levels (CL) above eCAP threshold and T levels '_' CL below C levels.)

○ Other: _____

Q7. Do you recommend eSRT for setting the C levels? *

○ No

○ Yes — (What specific relationship do you maintain between the eSRT and the behavioral C levels? e.g., setting C levels '_' CL below the eSRT.)

○ Other: _____

Q8. How do you usually handle Dynamic Range (DR) setting during mapping? *
Select all that apply. Complete the table separately for Pediatric and Adult recipients.

Pediatric & Adult population

Mapping Session	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**>50**
Switch-on Progressive map 1	☐	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 2	☐	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 3	☐	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 4	☐	☐	☐	☐	☐	☐	☐	☐
Follow up 1	☐	☐	☐	☐	☐	☐	☐	☐
Follow up 2	☐	☐	☐	☐	☐	☐	☐	☐
Follow up 3	☐	☐	☐	☐	☐	☐	☐	☐
Follow up 4	☐	☐	☐	☐	☐	☐	☐	☐
Follow up 5	☐	☐	☐	☐	☐	☐	☐	☐

Q9. If eSRT or eCAP measurements cannot be obtained for setting stimulation levels, what would be your next clinical approach?

_____

Q10. Do you CHANGE default settings for Processing Strategy? (Default: ACE.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q11. Do you CHANGE default settings for Stimulation Mode?(Default: MP1+2.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q12. Do you CHANGE default settings for Channel Rate? (Default is 900.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q13. Do you CHANGE default settings for Maxima? (Default is 8.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q14. Do you CHANGE default settings for Pulse Width? (Default is 25 μs.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q15. Do you CHANGE default settings for Volume Adjustment? (Default is 20% of Dynamic Range.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q16. Do you CHANGE default settings for Loudness Growth? (Default: 20.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q17. Do you CHANGE default settings for Frequency Table Power? (Default is auto.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q18. Do you CHANGE default settings for Volume and Sensitivity? (Default: Volume is 6, Sensitivity is 12.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q19. Which SmartSound iQ preprocessing features are typically recommended to be enabled for adult & school-age Cochlear recipients? *

Select all essential features.

Pre-processing startegy	**Pediatric**	**Adult**
SCAN (Automatic Scene Classifier)	☐	☐
SCAN 2	☐	☐
SCAN 2 FF	☐	☐
Forward- focus	☐	☐
ADRO (Adaptive Dynamic Range Optimization)	☐	☐
ASC (Automatic Sensitivity Control)	☐	☐
SNR-NR (Signal-to-Noise Ratio Noise Reduction)	☐	☐
WNR (Wind Noise Reduction)	☐	☐

MED-EL

Kindly fill all the required details. This will take approximately 5–10 minutes

Q1. Which methods do you commonly recommend to determine the LSL (THR) and USL (MCL) during the switch-on session for MED-EL recipients? * *Select all methods or approaches you commonly use.*

Methods	Pediatric	Adult
eCAP / ART responses	☐	☐
eSRT Response	☐	☐
Behavioral Response	☐	☐
Patient feedback on loudness & comfort during live stimulation	☐	☐
Comparing with intra-op measurements for initial reference	☐	☐
Based on previous experience or clinic protocol	☐	☐
Relying primarily on manufacturer-recommended default mapping templates	☐	☐

Q2. Do you recommend eCAP/ART for setting the levels? *

○ No

○ Yes — (Please describe how you relate these responses to THR and MCL, e.g., setting MCL '_' charge units above/below eCAP threshold.)

○ Other: _____

Q3. Do you recommend eSRT for setting the MCL? *

○ No

○ Yes — (What specific relationship do you maintain between the eSRT and the MCL? e.g., setting MCL '_' charge unit above/below the eSRT or maintaining MCL at the level of eSRT.)

○ Other: _____

Q4. To what percentage of the MCL do you recommend locking the threshold (THR) level when mapping MED-EL CI recipients? * *Select the most applicable option.*

○ 8% of MCL

○ 10% of MCL

○ Adjusted individually depending on behavioural or objective responses

○ Other: _____

Q5. What will be the upper limit of MCL (in charge units, Qu) you go up to during each mapping situation? * *Select all that apply. Complete the table separately for Pediatric and Adult recipients.*

Mapping Session	**20 – 25**	**25 – 30**	**30 – 35**	**35 – 40**	**40 – 45**	**45 – 50**	**>50**
Switch-on Progressive map 1	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 2	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 3	☐	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 4	☐	☐	☐	☐	☐	☐	☐
Follow up 1	☐	☐	☐	☐	☐	☐	☐
Follow up 2	☐	☐	☐	☐	☐	☐	☐
Follow up 3	☐	☐	☐	☐	☐	☐	☐
Follow up 4	☐	☐	☐	☐	☐	☐	☐
Follow up 5	☐	☐	☐	☐	☐	☐	☐

Q6. If eSRT or eCAP measurements cannot be obtained for setting stimulation levels, what would be your next clinical approach?

_____

Q7. Do you CHANGE default settings for Processing Strategy? (Default is FS4.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q8. Do you CHANGE default settings for Frequency Bands? (Default is logarithmic FS — 100 to 8500 Hz.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q9. Do you CHANGE default settings for AGC Compression Ratio? (Default is 3:1.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q10. Do you CHANGE default settings for AGC Sensitivity? (Default is 75%.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q11. Do you CHANGE default settings for MapLaw? (Default is logarithmic with compression=500) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q12. Do you CHANGE default settings for Volume Mode? (Default is IBK.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q13. Do you CHANGE default settings for Microphone Directionality? (Default is 'Natural'.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q14. Do you CHANGE default settings for Wind Noise Reduction? (Default is 'Mild'.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q15. Which preprocessing features are typically recommended to be enabled for school-age CI recipients? Please specify the names.

_____

Q16. Which preprocessing features are typically recommended to be enabled for adult CI recipients? Please specify the names.

_____

ADVANCED BIONICS

Kindly fill all the required details. This will take approximately 5–10 minutes.

Q1. Which methods do you commonly recommend to determine the LSL (T) and USL (M) during the switch-on session for AB recipients? *

Select all methods or approaches you commonly use.

Methods	Pediatric	Adult
eCAP / NRI responses	☐	☐
eSRT Response	☐	☐
Behavioral Response	☐	☐
Patient feedback on loudness & comfort during live stimulation	☐	☐
Comparing with intra-op measurements for initial reference	☐	☐
Based on previous experience or clinic protocol	☐	☐

Q2. How will you estimate M level from eCAP / NRI / t-NRI?

_____

Q3. Do you recommend using eSRT for setting the M level? *

○ No

○ Yes — (What specific relationship do you maintain between the eSRT and the M level? Please specify below.)

○ Other: _____

Q4. Do you CHANGE the default settings for the percentage used to lock the threshold (T) level? (Default is 10% of M.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q5. In your clinical practice, which method do you primarily prefer for measuring loudness (M) levels in AB CI recipients? *

☐ Speech Burst stimulation across multiple channels (default method)

☐ Single-channel (individual electrode) tone-burst stimulation

☐ Global adjustment in Live Speech mode followed by loudness balancing

☐ Other: _____

Q6. What will be the upper limit of M level (in charge units) you go up to during each mapping situation? * *Select all that apply. Complete the table separately for Pediatric and Adult recipients.*

Mapping Session	**Below 100**	**100 – 150**	**150 – 200**	**200 – 250**	**250 – 300**	**>300**
Switch-on Progressive map 1	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 2	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 3	☐	☐	☐	☐	☐	☐
Switch-on Progressive map 4	☐	☐	☐	☐	☐	☐
Follow up 1	☐	☐	☐	☐	☐	☐
Follow up 2	☐	☐	☐	☐	☐	☐
Follow up 3	☐	☐	☐	☐	☐	☐
Follow up 4	☐	☐	☐	☐	☐	☐
Follow up 5	☐	☐	☐	☐	☐	☐

Q7. If eSRT or eCAP measurements cannot be obtained for setting stimulation levels, what would be your next clinical approach?

_____

Q8. Do you CHANGE the default settings for Sound Coding Strategy? *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q9. Do you CHANGE the default settings for Pulse Width? (Default is APW I.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q10. Do you CHANGE the default settings for Gain? (Default is 0) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q11. Do you CHANGE the default settings for Volume Max (default 20%) & Volume Min (default 50%)? *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q12. Do you CHANGE the default settings for Microphone Sensitivity? (Default is 0 dB.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q13. Do you CHANGE the default settings for IDR? (Default is 60 dB.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q14. Do you CHANGE the default settings for Audio Mixing? (Default is 50/50 Mic/Aux.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q15. Do you CHANGE the default settings for Microphone Mode? (Default is Omnidirectional.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q16. Do you CHANGE the default settings for Filter? (Default is Extended Low.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q17. Do you CHANGE the default settings for AGC? (Default is 2 – Dual Loop.) *

○ No

○ Yes — (Please describe the situations in which you change this setting.)

○ Other: _____

Q18. Which AB noise management features do you utilise in situation-specific programs for both adult and pediatric groups? *

Pre-processing startegy	**Pediatric**	**Adult**
UltraZoom (adaptive directional microphone mode)	☐	☐
ClearVoice algorithm (Low / Medium / High attenuation level)	☐	☐
ZoomControl (fixed directional mode for specific directions)	☐	☐
T-Mic 2 (natural acoustic effects of the auricle)	☐	☐