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Prognostics Factors of Cochlear Implant in Adults: How Can We Improve Poorer Performers?

Bernard Fraysse and Chris J. James

Abstract

Rehabilitation for any cochlear implant (CI) recipient is a process having the aim of taking the necessary steps to enable users to achieve their best possible auditory outcome. It involves all stages of interaction including evaluations for candidacy, device selection, preoperative counseling, surgical intervention, device activation, post-implant support, evaluations of progress, and hearing training. Since rehabilitation is an ongoing process, it becomes critical to determine what is sufficient, that is, how intense the follow-up program must be, especially since there is substantial variability for results on outcome measures that assess progress in hearing function and abilities after implantation.

Keywords: rehabilitation, cochlear implant

1. Introduction

Rehabilitation for any cochlear implant (CI) recipient is a process having the aim of taking the necessary steps to enable users to achieve their best possible auditory outcome. It involves all stages of interaction including evaluations for candidacy, device selection, preoperative counseling, surgical intervention, device activation, post-implant support, evaluations of progress, and hearing training. Since rehabilitation is an ongoing process, it becomes critical to determine what is sufficient, that is, how intense the follow-up program must be, especially since there is substantial variability for results on outcome measures that assess progress in hearing function and abilities after implantation [4].

A primary aspect of our rehabilitation approach is early identification of the challenges associated with the remediation of adult cochlear implant users who demonstrate poor results on objective measures. A poor performer may be described as one who achieves “... limited performance after taking in account the preoperative biographic factors during counselling the patient and anatomical factors electrode insertion” [1].

The approach we present in this chapter is based on years of experience and research in our facility and in cooperation with other multicenter studies. Nearly 50% of our patient population will be managed, postoperatively, through conventional (passive) auditory rehabilitation, which means managing all aspects related to device use and counseling and encouraging patient-driven practices. Patient-driven practices take advantage of everyday life encounters, whether it be through

exposure to TV and videos/movies without captioning, audiobooks, telephone use, social media communication applications (Skype, FaceTime, WhatsApp, etc.), family encounters at group get-togethers, one-on-one with co-workers or friends and family, etc. [2]. The remaining patients will require further, detailed investigations and personalized active rehabilitation. Experience shows that the early identification of those requiring more active rehabilitation training leads to better outcomes. It results in a reduction in the number of visits for those requiring less direct intervention and allows our clinical specialists to concentrate on improving the outcomes of poorer performers.

2. Preoperative counseling

Although candidates receive comprehensive counseling throughout their rehabilitation program, the pre-implant sessions lay the foundation for establishing realistic expectations. This goal is supported by employing a predictive model from which the basis for expectations can be established. The model predicts the sentence recognition score of CI users 1 month after activation. It was derived and simplified from the analysis by [1]. The model takes into consideration only the duration of severe-to-profound hearing loss (HL) and one key etiology, congenital hearing loss, which produced significantly lower scores than other etiologies (including “unknown” causes). The formula is easily applied:

$$\text{Predicted score} = 90 - 0.5 \times \text{years HL} - 50 \text{ (if congenital HL)} \quad (1)$$

where 90 represents the expected score (out of one hundred) for a good performer, which is reduced by 0.5 points per year of severe-to-profound hearing loss and further reduced by 50 points if the etiology was congenital HL. If the etiology is not congenital, then the formula is only 90 minus half the number of years of HL. The predictive model is not valid for cases of labyrinthitis (e.g., chronic otitis and autoimmune disease), where the findings of [1] indicated considerable variability and generally poor outcomes. Our evidence from adults suggests a priori that those with congenital HL are expected to yield poor performance scores. As an example, for deafness acquired in adulthood for a duration of 40 years, the prediction would be a score of 70; however, if the deafness had been congenital, the score would be 20. Another example for a person with short-term deafness of 6 years would yield a higher score ($90 - 3 = 87$). The predictions are valid assuming that the best surgical outcome is obtained in terms of electrode array position and insertion depth (see below).

As will be discussed later, outcome scores could be worse than expected for any CI user and would indicate the need for ongoing rehabilitation intervention. Individuals with poorer than expected scores would be considered poor users. In other words, additional factors may intervene with the duration of deafness and etiology to affect the results, many of which can be investigated and evaluated only after implantation.

Based on the population data from [1], we generated a distribution of scores assuming ideal electrode position before activation, that is, no dislocation and insertion depth within the recommended limits. The resultant median score was at approximately 70/100 (**Figure 1**, raw scores, left).

If there is to be some effect on the overall population performance, we need to choose a relatively high threshold below which we will apply active rehabilitation. The rationale is that bringing up the performance of the lowest half of the population is a worthy, and likely, achievable aim, and, therefore, we set the threshold

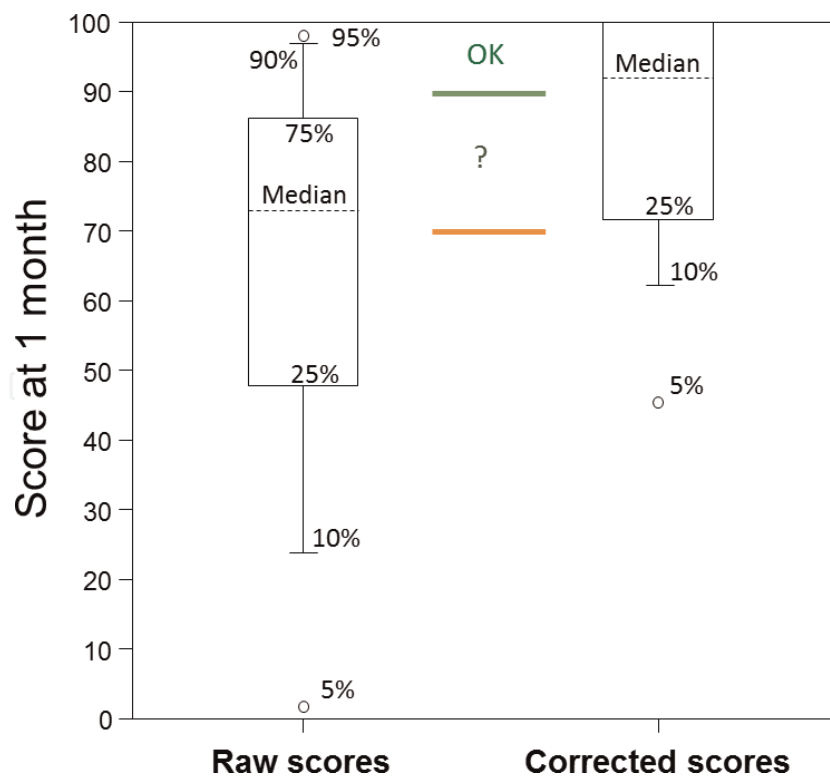


Figure 1. Distribution of sentence recognition scores assuming correct electrode array position (raw scores) and, in addition, removing the effects of duration of deafness and etiology (corrected scores). Number labels represent percentiles for the population. The raw score distribution helps us in preoperative counseling; the corrected scores help us in remediation 1-month post-activation.

score at 70. If the result of the prediction is less than 70, the expectation is that the new user will require active rehabilitation in addition to the conventional recommendations of patient-directed listening activities.

The information gained from the model helps in setting realistic expectations during pre-implant counseling and in early planning by clinical specialists for potential rehabilitation needs. One could be advised that the challenges of adapting to the new sensations may be slow, requiring many visits not only for device fitting but also for direct practice. On the other hand, others might be advised that they may experience a rapid adaptation and likely understand most of what people say if listening in quiet circumstances. Early advice about whether to expect slow or rapid progress can also serve as a motivational tool. If new CI listeners understand how involved they will need to be once their CI is activated, they can be motivated to engage in listening activities as opposed to simply expecting to be fixed. Motivation has a significant impact on adult learning [3]. It may first be established by setting appropriate expectations.

During pre-implant counseling, patients are advised that there are many factors that influence results and that these will be discovered systematically beginning at the first activation of the device and at the first-month evaluations. Indeed, although patient outcomes may turn out quite differently than expected, given that not all influencing factors can be known and that each CI user is unique, early, realistic expectations establish the foundation for accepting new sound sensations.

Our research has shown that the main factors that influence performance are related to circumstances of etiology and duration of deafness, outcomes of surgical intervention of insertion depth and dislocation, and central aspects of linguistic and neurocognitive skills [1]. The variability seen in speech recognition scores are described in **Tables 1** and **2**.

	In quiet	In noise (10 dB SNR)
Etiology	0.34***	0.25**
Duration of deafness per year	0.06*	0.08**
Total in percent	40%	33%

p<0.05, **p<0.01, *p<0.001.*

Table 1.
Patient history factors explaining significant variance () at 1-month post-activation with respect to outcomes of sentence recognition.*

	In quiet	In noise (10 dB SNR)
Proportion of electrodes in the scala media	0.14**	0.13**
Insertion length per degree	0.09***	0.08***
Total in percent	23%	21%

***p<0.01, ***p<0.001.*

Table 2.
Surgical factors explaining significant variance () at 1-month post-activation with respect to outcomes of sentence recognition.*

2.1 Main factors influencing performance

A thorough patient history is needed to gain details of etiology and duration of hearing loss. Our studies indicate that 6–12% of the total variance for speech understanding in quiet is related to the duration of deafness and approximately 30% is related to the etiology [1]. For instance, congenital HL produces significantly poorer scores in the short term and chronic otitis media in the long term [1, 4]. Certain diseases may produce greater damage to the cochlea resulting in poorer signal transmission after implantation such as bony tissue growth induced by meningitis or trauma. Speech signals may be distorted more than expected by poor neural representation of speech features due to anatomical distortions from diseases that affected the hearing [5]. The challenge is that characteristics of even a known etiology may not be clear.

Details concerning the duration of deafness may be elusive; for instance, defining the specific onset of significant hearing loss may be difficult to determine and impacted by hearing aid use (i.e., how much was one or two hearing aids actually used (e.g., [6]), was the loss progressive, how rapid did the loss develop, and so forth). The impact of unanswered questions may be seen in later performance, especially in cases of unexpected poor performance. Applying the predictive model helps estimate potential outcomes.

3. Surgical intervention

The physiological/structural condition of the cochlea may affect electrical stimulation. A full battery of objective measures available to the surgical team conducted pre- and intraoperatively helps guide preoperative planning and postoperative device programming [7]. Aspects to consider are the size of the cochlea [8], the type of electrode design (straight or perimodiolar) and its potential insertion depth, as well as whether the insertion was solely into the scala tympani or dislocated into the scala vestibuli. In our study, scala dislocation reduced scores by 12–25 points at the 1-month evaluation interval [1]. Thus, selection of the implant device, in cooperation with the patient wishes, anatomical considerations and

surgical intervention each play a role in performance outcomes and account for 8–13% of the variance in performance scores at 1 year.

Preoperatively, it is essential to choose the appropriate electrode type and to target an insertion depth of one cochlear turn (i.e., $\sim 360^\circ$) as proposed by [1]. This aim is also supported by [9], who indicated a negative correlation between word scores and electrode insertion depth measures. The study by Lazard et al. [6] also found poorer outcomes for the most deeply inserted electrodes. These results need to be tempered against the potential of having larger frequency-place mismatches for shallower electrode insertion depths as discussed in the following section.

Any information that contributes to the first activation and mapping for listening programs is useful. The insertion depth provides a reference for better accessing appropriate frequency allocations relative to cochlear tonotopic organization [8]. Electrode design also plays a role not only because of its insertion characteristics, straight or curved, but also because of the spacing between contact electrodes.

Our studies have shown that an insertion depth of $300\text{--}360^\circ$ yielded optimal performance. Moderate shifts in frequency-to-place may easily be accommodated by the listener, but larger shifts >1.5 octave may affect auditory performance, and adaptation may take longer [10]. Electrode placement can be detected by routine intraoperative X-ray. Shifts were approximately one octave for Nucleus Implants with 360° insertion depth, with shifts still <1.5 octaves for 300° , for the default frequency allocation table. For other devices, the shifts appeared greater for the same insertion depths due to the specific default frequency-to-electrode allocation used in the device. Thus, these devices may work most effectively with greater insertion depths or, alternatively, with the use of customized frequency allocation tables that can be adjusted in the specific programming software.

Avoiding a frequency-place shift of greater than 1.5 octaves will probably produce the best result for a given insertion depth. However, further optimization may be achieved by limiting insertion depth at surgery or deactivating the most apical electrodes (e.g., [11]). If electrode arrays are found to be inserted greater than one turn, we may consider deactivating the most apical electrode contacts to simulate the ideal insertion depth. This is consistent with the work of [8] whose temporal bone studies found correlations between specific insertion depth angles and tonotopic frequency locations. Deeper insertion, greater than 360° , was associated with frequencies lower than ~ 900 Hz; however, one needs to consider that the spatial density of spiral ganglion cells increases considerably past this point, such that cross-turn stimulation can easily occur. As mentioned, depending on the device type, if the active insertion depth is limited to 360° , then it may be necessary to modify the frequency-to-electrode allocation through programming to avoid excessive frequency-place shifts.

3.1 Intraoperative tests

After the electrode has successfully been placed into the cochlea, monitoring its position is accomplished through intraoperative X-ray [7]. The neural activity of device-activated electrical stimulation is evaluated with neural response telemetry (NRT), which replicates electrically evoked compound action potentials (ECAP). The NRT responses provide an objective measure of the integrity of auditory nerve function when stimulated through a CI [12, 13]. It can be administered intra- and postoperatively; a thorough description of the method is described by [14], and the newer application of auto-NRT is described by [15]. Intraoperatively, the focus is on gaining details relating to whether the device is operational and whether the responses per electrode indicate that electrodes are within the scala tympani and

close enough to activate auditory nerves. Those outside, mislocated into the scala vestibuli, may yield no NRT response [13].

4. Device activation

It is our practice to provide two initial programs. The first is a standard, default program recommended by the manufacturer’s specifications, and the second has frequency-to-electrode allocation, as indicated above, based on the surgical outcome indicated by X-ray findings for the particular patient. We ask the new user to switch between the two programs in order to experience whether one is more pleasing and/or effective than the other. We speculate that postlinguistically deafened adults will have difficulty adjusting to the sound quality for the standard program and choose the second that was derived from the intraoperative findings and one that avoids a “boomy” sound indicative of a mixing up of low-frequency sensations produced by apical cross-turn stimulation.

The second program will usually take into consideration the possible frequency-place mismatches relative to insertion depth, that is, the physical position of the electrode contacts. The default frequency allocations provided in the programs of the sound processor may need adaptation [1], as discussed above.

All new users are sent home for a month after receiving counseling about ways in which they can direct their own rehabilitation through practice at home and in different environments in which they commonly find themselves. They are also reminded of expectations, and family members and/or significant others are provided counseling in ways to support the new CI user. It is an option to test the subject for sentence understanding in quiet during the first days of activation. We have found that if a new user scores >60% at day 1, they will obtain scores >80% by the 1-month follow-up (Figure 2). These CI users will likely need little active rehabilitation and already appear to be on a good course. Thus, early performance is indicative of later, long-term performance.

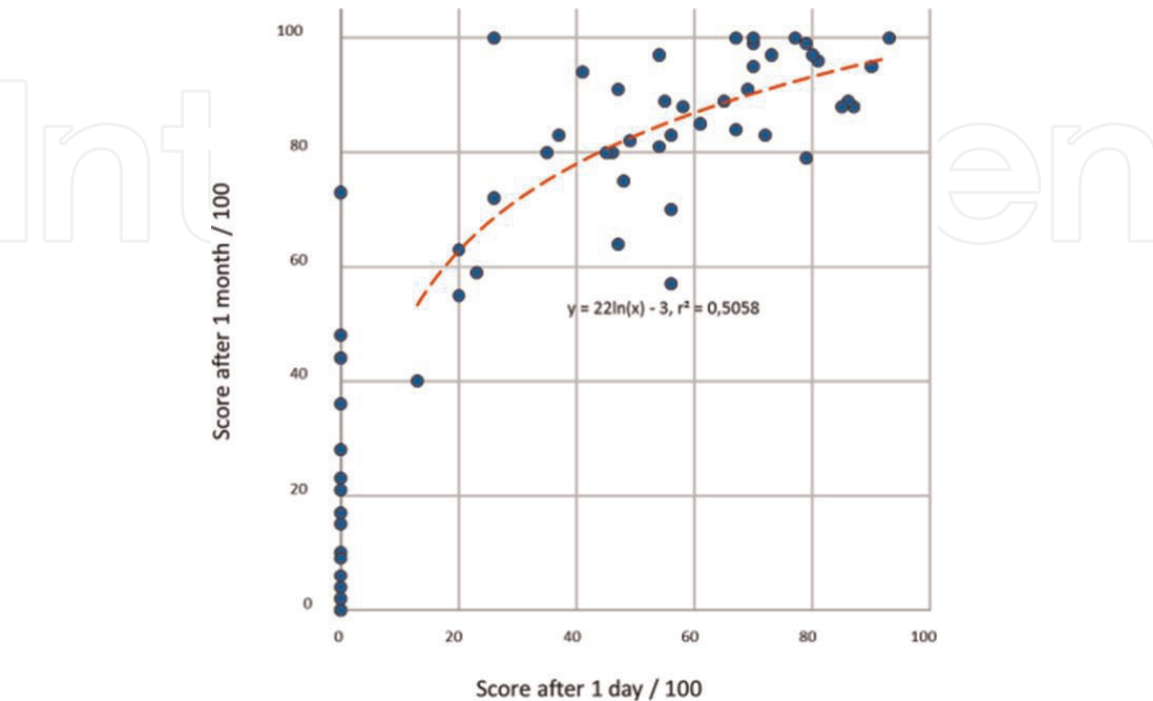


Figure 2
Sentences in quiet evaluated at 1 day and at 1 month, post-implant.

In fact, the development of speech understanding with a CI does not follow a linear function with time. High sentence recognition scores can be obtained at only 1 day after activation, and the first 2 weeks are as important as the next 6 months and the following 2–3 years. It is not fully understood why CI user's individual performance progress at different rates. In James et al. [1], they observed different patterns of growth in scores, both in quiet and in noise, from the first month, but always following a logarithmic growth curve, such that each additional increment in performance took twice as long as the preceding increase.

5. Optimizing maps and initial evaluations: 1-month follow-up

Significant improvement will usually take place from activation to 1 month; thereafter increases continue but at a much slower pace. Increases in understanding will be about the same after 6 months of experience for sentences in quiet. Adapting to any new sensation requires time; an auditory signal presented through a CI will always first be perceived as very different. It is unclear why some new users immediately accept the new input and others reject it as sounding too foreign. In any case, we believe a month of exposure to the new signals is the minimum time to allow all patients for the initial accommodation to the input. Thus, all CI users are re-evaluated at 1 month.

By the first month, there already is access to data logging to confirm speech processor program usage, the users are usually aware of which program they might prefer, and the speech recognition scores in quiet will have been tested. The outcome of sentence recognition testing and CI user reports may indicate a need for alternative device programming. Looking at **Tables 1** and **2**, approximately 40–50% of the variance is not explained by the patient-related and surgical factors. There are dynamics in play that may never be known such as the impact of certain disadvantages (insertion depth, dislocation, cochlear condition at surgery) and others. Alternative programs (differing mapping parameters) may also take into consideration speed of stimulation (refractory period) as demonstrated through different stimulation rates or spread of excitation via channel selectivity (perhaps deactivating particular electrodes). These more advanced aspects of programming, however, are taken into consideration at every programming session, as indicated. Optimizing sound processor programs is the most direct way to compensate for the degraded speech signals delivered through a cochlear implant.

The one aspect to be evaluated may be behavioral responses to changes in stimulation rate. Postoperative NRT testing may be indicated to assess neural recovery functions to gain information about beneficial stimulation rates. From their studies on the temporal characteristics of auditory nerve stimulation via CIs, [16] suggest that the programmed stimulation rate relates to the refractory period of the nerve. CI user performance may be addressed, in some cases, by reducing the stimulation rate. It is not possible to define when the so-called aging process begins, but it is clear that neural transmission times slow as one ages [17, 18]. Older CI users may be more susceptible to stimulation rate effects. Any means of enhancing auditory signals that occur in the presence of poor temporal processing will provide a better foundation for learning to overcome perceptual difficulties.

5.1 Initial performance evaluations

During this test interval, it is possible to identify, with more clarity, the individuals who might be classified as potentially having poor performance. By definition, on average, approximately 50% of recipients will demonstrate “normal” performance, i.e., 70% or greater scores for sentence understanding in quiet. However, if

we consider individuals who present with no negative patient-related factors, they should perform better than 70% and on average around 90%. This is, then, the second use of the model. The prediction of the model is compared with the actual score at 1-month post-activation; if the actual score is lower than the prediction, it points to a need for remedial action. Thus, two groups are identified who will undergo further evaluation: those individuals who are overall “poor” performers and achieve less than 70% and those whose actual scores are below their predicted scores from the model. The others with satisfactory performance will be advised to continue their own patient-directed practices (passive rehabilitation). Complete remediation of the effects of duration of deafness and congenital hearing loss would result in a “corrected” distribution as shown in **Figure 1**, with an overall average (median) performance at about 90% and only 25% of cases performing less than 70%. Such an improvement is the aim of the remedial actions described in the following sections.

Figure 3 illustrates the further needs of the less-than-satisfactory poor user or overall poor performer. The results of intraoperative NRT findings are compared, and mapping considerations are applied to create alternative programs, as described above. This is considered part of the bottom-up approach. Other, more specific analytic psychophysics may also be included in a rehabilitation program, if indicated [5].

A poor performer will require thorough auditory evaluations and cognitive testing. Given that the predictive model accounts for approximately 63% of the variance in performance, the contribution of cognitive factors must be considered. If poor performance is identified or suspected, steps are taken to investigate the factors that may be affecting the user’s ability to process the sound information they are receiving through the CI including the central aspects of linguistic and neurocognitive skills influencing communication strategies as outlined in **Figure 4**.

Evaluations that yield scores within normal limits for phonological sensitivity and working memory point to motivation issues and, therefore, intense counseling are provided without the need for active rehabilitation support. If poor linguistic skills are revealed, training in phonological aspects is indicated. Evaluations

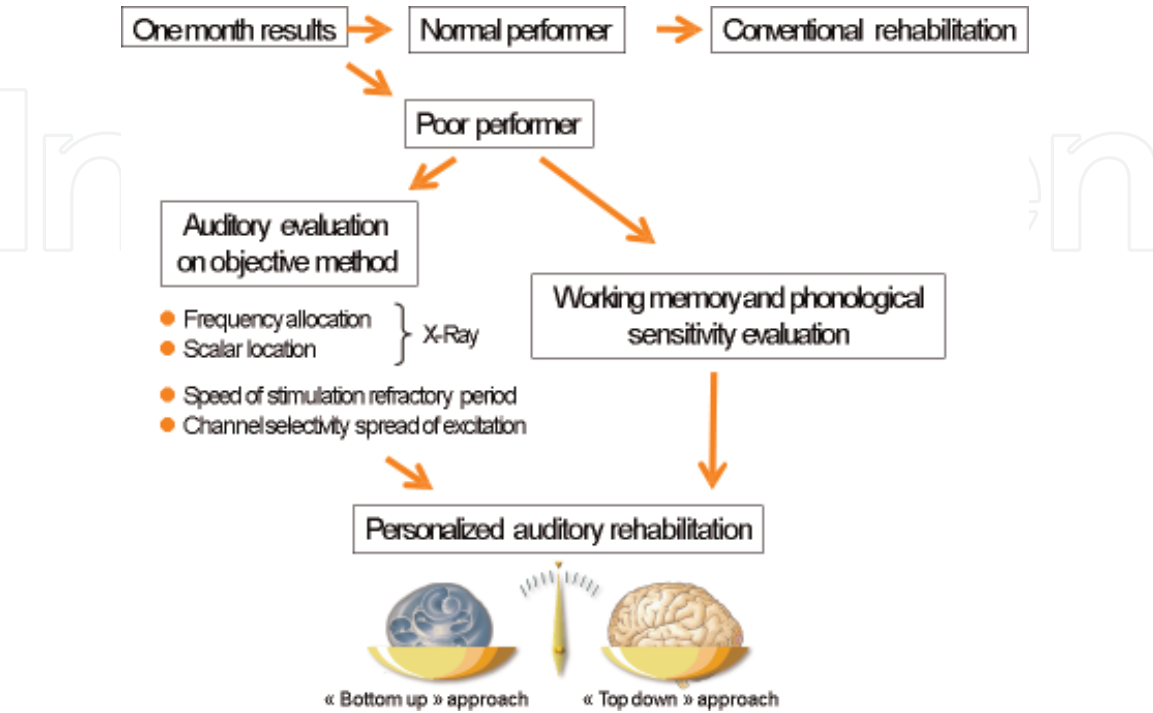


Figure 3.
Flow diagram illustrating the development of patient-specific rehabilitation strategies.

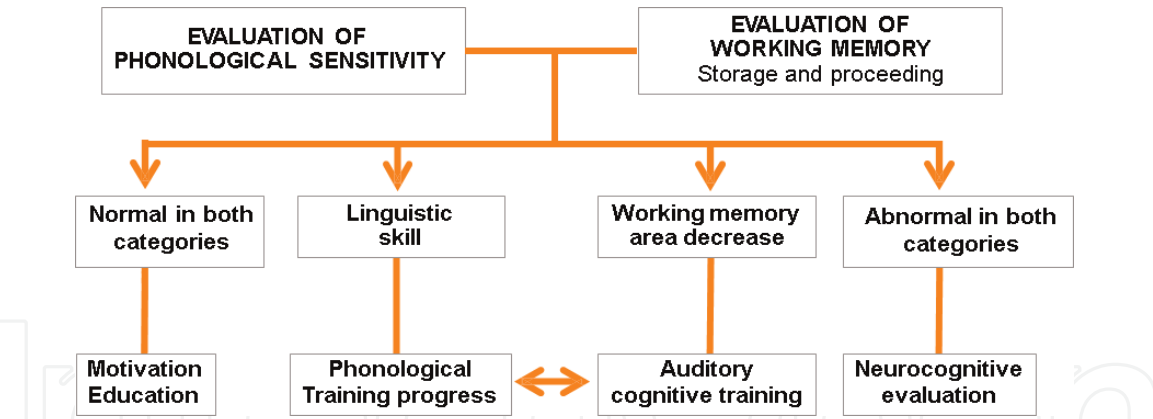


Figure 4.
Indications for rehabilitation training in poorer performers.

demonstrating poor working memory lead to applying auditory cognitive training; however, if the results of the evaluations point to an abnormal working memory and phonological sensitivity, neurocognitive evaluations are pursued.

It is beyond the scope of this chapter to supply specific evaluation and training materials. Methods should be consistent with culture and the available materials in a particular language and according to the consensus within the country. A review of rehabilitation methods that can be applied to cochlear implant users can be found in [19] and in [20]. In common, however, is that counseling will focus on the CI user gaining confidence in associating the digitally coded sounds that are presented through a CI with meaningful speech. It is advisable to remember that a CI user needs adequate time to experience modifications; even poorer users do not require constant reprogramming. In general, poorer users are seen at the clinic in 3-month intervals, and better performers are seen in 6-month to annual intervals. Interactions with local speech-language therapists are the main support for poorer performers with frequent liaison between the therapist and specialists within our clinic.

5.2 Rehabilitation approach

Harris et al. [2] point out that no standardized rehabilitation approach exists despite decades of CI use in individuals of all ages. Agreement is found in the concept of tailoring post-implant rehabilitation to the needs of the individual user [21, 22]. The challenge is that long-term rehabilitation may be indicated but that limitations in funding through reimbursement are available mainly due to a lack of evidence for demonstrable effects [2, 18]. Our experience, and that of [21], indicates that rehabilitation may be required for as long as 2 years to reach a so-called performance plateau.

Conceptually, rehabilitation can be divided into two approaches, top-down or bottom-up [23]. Methods that focus on bottom-up procedures utilize materials relating specifically to the input signals possible via a CI, that is, how a signal is processed. The elements of sound serve as building blocks, starting with the smallest unit (i.e., a phoneme). Relative to a CI, acquiring responses to the psychophysical tasks (temporal, spectral, and amplitude cues) during the mapping process entails a bottom-up approach, which is an analytic method. Some of these tasks may be adapted for auditory training purposes [5].

5.2.1 Synthetic-cognitive training (top-down)

Top-down methods represent a synthetic approach and have the aim of enhancing communication strategies through cognitive processing. As mentioned,

outcomes of the predictive model accounted for more than 60% of the variance in quiet and 50% of the variance in noise for sentence recognition scores obtained at 1 month after CI activation [1]. Thus, cognitive factors play a large role in the wide variance seen in performance scores obtained by the adult CI population. Optimizing a personalized rehabilitation strategy must take into consideration the cognitive dynamics of speed of processing, working memory, and attention and executive function [23].

The input from any CI is inherently degraded compared to that available in normal-hearing individuals or, indeed, to those able to utilize a hearing aid effectively. Aging may play a role, slowing the process of learning [18] to accommodate to speech sounds presented as a new, seemingly unusual, set of sounds. Cognitive training should take into consideration the age of the CI user. In fact, it has been suggested that older CI users (>80 years) may benefit more from rehabilitation than younger users. A top-down approach may be the most appropriate approach for the older population [18].

5.3 Role of plasticity

It is unknown to what degree the brain reorganizes speech when confronted with hearing loss [24]. We studied the dynamics of reversed cross-modal plasticity by TEP brain imaging during speech tracking before and after CI at two time points [25]. Essentially, as a result of auditory sensory deprivation, regions in the brain associated with perceiving visual input are activated during speech communication. After implantation, neuroplasticity is demonstrated as the brain recruits more auditory networks during tests of speech recognition. Olds et al. [26] confirmed these findings using the functional near-infrared spectroscopy (fNIRS) imaging technique. They observed cortical reorganization and suggested that listening effort may be involved in the cortically activated regions. They used several speech recognition tests, including sentences, with the CI turned off and on. This may account for the activated regions seen in our study, although neither of the test intervals utilized direct auditory input. We speculate that during hearing deprivation, sensitivity to voice progressively decreases. Anderson and Kraus [20] refer to this as “deprivation-induced changes in auditory mapping.” Once sound is reintroduced, the more visually focused cortical regions reassert into the voice-sensitive regions. This cross-modal reactivation shows the cooperation between visual and auditory cortex. Thus, a profound aim of active rehabilitation is to take advantage, and encourage, reverse plasticity to aid in restoring cortical preference to meaningful auditory signals. This need is also recognized by other authors [27].

6. Ongoing post-implant support, evaluations of progress, and hearing training: 6-month follow-up

Testing speech in noise takes place at 6 months. We have seen that the relationship between performance in quiet and in noise is highly correlated. The early performance in quiet is manifested in the 6-month scores (see **Figure 1**). Testing at a signal-to-noise ratio (SNR) of 10 dB creates a reasonable challenge and serves as a further indicator of who requires continued rehabilitation. We have observed that it is possible to identify CI users who have demonstrated early success or a steep learning curve. The remaining patients continue as poor users needing support and ongoing counseling to maintain their motivation. With continued exposure to auditory stimulation, they can be advised that still more progress is possible for them.

Increases continue even up to 3 years, but the incremental gain is much less than what is usually seen during the first 6 months of use.

7. Summary

We summarize the complete rehabilitation process in **Figure 5**. Pre-implant counseling based on the results of the predictive modeling; surgical planning focusing on considerations to the size of cochlea and type of electrode; and intraoperative testing using X-ray findings to confirm placement and depth of insertion along with NRT to confirm neural interface via electrostimulation all take place before initial activation. This includes counseling that may need to modify expectations based on surgical outcomes and intraoperative evaluations. Two MAPs are developed at first fitting where one is based on intraoperative findings. At 1 month, observations gathered from data logging, along with comparing sentence scores in quiet to the predictive model, provide an indication as to whether a new CI user will need specialized rehabilitation. Again, counseling may need to guide and modify expectations. The type of rehabilitation is determined, usually a combination of both bottom-up and top-down approaches. At the 6-month interval, testing in noise is applied, and further adaptations to the MAPs are made. In the future, we hope to extend the predictive model to include factors for analysis of performance in noise for the long term. Continued appropriate rehabilitation after 6 months ensues, and continued counseling insures that the CI user understands the need to support hearing progress with ongoing rehabilitation, if needed.

Providing viable rehabilitation to adult poor performers lies within the realm of detective work. In the early stages, it provides affirmative counseling based on predictive modeling and effective surgical planning and its implementation. Counseling patients with realistic expectations, however, takes place throughout the entire rehabilitation process. There will always be differences in outcomes, but having a full array of options based on objective measures and individual case history will guide the specialist to advise for optimal use of their hearing abilities. Motivation is a very important component of success, and this needs to be reinforced especially for this population who, often, have unrealistic expectations (this includes the family and supporting individuals).

As CI specialists, we provide access to direct rehabilitation and rehabilitation support. Specialized rehabilitation, given the wide variability in patient outcomes,

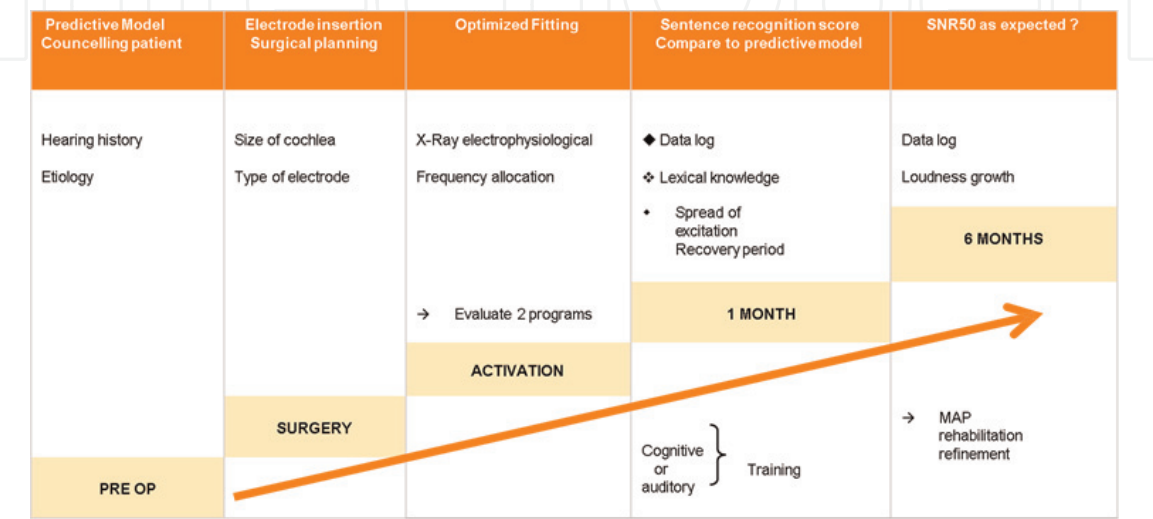


Figure 5.
Stages of the rehabilitation process.

ideally should be modeled to the specific needs of each individual CI user. To achieve the best level of performance possible, programming options will continually be investigated, supported by patient-directed auditory experience and phonologic and cognitive training, when necessary.

We have discussed only the factors that may influence the post-implant performance of adult poor users, giving guidance on how best to examine the factors that affect performance. Our responsibility as clinicians is to offer an adult patient-user guidance that leads to an improvement in their quality of life through better hearing. We aim to utilize professional time efficiently and effectively, and we aim to concentrate on those who need post-implant therapy rather than providing standard rehabilitation strategies that may miss some and waste time for others.

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Declaration

Author CJJ is an employee of Cochlear, manufacturer of cochlear implants.

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