Remote Mapping via Tele audiology in Cochlear Implant Patients

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ABSTRACT

This review consists of various studies analysis about cochlear implant remote mapping effectiveness in nucleus

cochlear implant patients, for all ages, through specific equipment by experienced cochlear implant audiologists.

Purpose: the aim of this literature review is to spotlight multiple research studies and discuss whether Remote Mapping via Tele audiology in nucleus CI patients is equivalent to traditional in person programming for all ages.

Results: no significant differences were found for MCL, THR, audiometry and speech understanding for either remote or local fitting. Remote fittings took slightly longer than local fittings when only the fitting time itself was measured.

Conclusions: the results suggest that tele fitting was well received by CI users and is a viable alternative to local Mapping, even in young children with CIs. Although there are some limitations in terms of adaptability, tele fitting could be an effective means of delivering CI service to remote locations.

Keywords: *remote programming, remote fitting, teleaudiology, cochlear implant, telehealth, telemedicine*

INTRODUCTION

A cochlear implant (CI) is an implanted electronic hearing device, designed to produce useful hearing sensations to a person with severe to profound hearing loss, by electrically stimulating nerves inside the inner ear.

Patients of all ages with CI require regular programming visits with an audiologist upwards of eight to ten appointments in their first year of implantation (Hughes et al., 2012). During these visits, the audiologist adjusts various electronic settings that control how the implant stimulates the nerves inside the inner ear, such as adjustments in sensitivity to low-level sound or limits on loud sounds. This in turn changes how the patient perceives different sounds, such as speech or music in different environments. These adjustments can improve the patient's quality of life by improving their ability to understand speech, their comfort in loud environments or independence in performing daily tasks (FDA News, 2017). The U.S. Food and Drug Administration has approved a remote feature for follow-up programming sessions for the Nucleus Cochlear Implant System through a telemedicine platform. The remote programming feature is indicated for patients who have had six months of experience with their cochlear implant sound processor and are comfortable with the programming process (FDA News, 2017).

Remote programming adjustments for cochlear implants done through expert cochlear implants audiologists can reduce the burden to patients and their families, especially those who must travel great distances or need frequent adjustments.

METHOD

This literature review investigates several studies about the feasibility of nucleus cochlear implants patients depending on various factors, with the aid of database parameters, such as (Google Scholar, PubMed, and other research sources), using multiple keywords, for example, (Remote programming, Remote fitting, Tele audiology, cochlear implant, Telehealth, Telemedicine).

Thirty related articles were found; however, only those articles mentioning the manufacturer were included.

INCLUSION AND EXCLUSION CRITERIA

All studies before 2007 were excluded regard to uncommon remote mapping of cochlear implants in telemedicine, in addition to all studies that involved any other manufacturer but cochlear nucleus.

On the other hand, articles which studied the effectiveness of cochlear implant remote mapping, for children and adults, were included.

Seven studies matched the inclusion and exclusion criteria: Wesarg et al., 2010; Hughes et al., 2012; McElveen et al., 2012; Samuel et al., 2014; Hughes et al., 2018; Slager et al., 2019; Luryi et al., 2020. These studies assessed the use of tele practice for CI service delivery for Nucleus cochlear implant recipients.

In this review, measuring patient-specific psychological parameters will be considered to evaluate the effectiveness for Nucleus Cochlear implant recipients (children and adults), who lived far from cochlear implant

(CI) centers and underwent live and remote cochlear implant programming sessions, further to the impact on time and monetary cost.

Table 1 shows the mentioned psychological parameters.

Table 1. *Patient-specific psychological parameters.*

	Psychological Parameters
1.	Maximum Comfortable level (CL)
2.	Threshold level (TL)
3.	Pure-tone average (Audiometric threshold)
4.	Speech perception

RESULTS

As shown in table 2, in regards to speech perception testing using Consonant-Nucleus-Consonant (CNC) words, Hearing-in-Noise Test (HINT) and AzBio sentences, McElveen et al. (2012), Luryi et al. (2020), Samuel et al. (2014), and Slager et al. (2019) obtained no significant difference between LP and RP. However, Hughes et al. (2012), found less performance for speech perception in the remote condition, due to the lack of a sound booth, high background noise levels and longest reverberation times.

As for Audi¬ometry Threshold, McElveen, et al. (2012), Luryi et al. (2020), Samuel et al. (2014), and Hughes et al. (2018), indicated that Pure Tone Average (PTA), VRA and CPA were acceptable for both LP and RP sessions.

Luryi et al. (2020), Samuel et al. (2014), Hughes et al. (2012), and Wesarg et al. (2010) found no significant difference in T and C levels for both LP and RP sessions.

Regarding time and monetary cost, all the above studies conclude that telehealth is a cost-effective and safe way to deliver post-CI audiological care. For example, Luryi et al. (2020) obtained that, on average, patients in the United States spend 123 minutes for a 20-minute appointment with a healthcare professional, including travel and wait time. As for Samuel et al. (2014), in a country with large dimensions, traveling cost and time to the CI Center is high, many patients, especially children, are tired when they arrive to the appointment.

While Slager et al. (2019), found by conducting a survey under certain circumstances that 80% of subjects responded that they were likely to choose telehealth, 17% said they were neutral, and 3% said they were not likely. Hughes et al. (2018), emphasize that RP reduce time and travel burdens for families.

However, the main challenges in RP with young patients were related to the timing of communication between the programming audiologist and the test assistant at the remote site.

DISCUSSION

Telemedicine is defined as “the delivery of healthcare services and information via high-tech telecommunications technologies”. The importance of tele-medicine has been heightened by COVID-19 pandemic, Telemedicine has been adapted to the field of audiology, known as tele-audiology, to provide remote hearing screenings, diagnostic testing, intervention, and/or rehabilitation services (e.g., hearing aid adjustment, cochlear implant programming)

The included studies examined the feasibility of remote cochlear implant programming, specifically seeking whether mapping via remote programming is equivalent to live programming and can be completed safely and effectively, in both children and adults.

Wesarg et al. (2010), studied 69 recipients (57 adults, 13 pediatric) of the Cochlear Nucleus System from four centers. In this study, cochlear implants programming took a place in two sessions for each patient, by the same audiologist. The first session was a face-to-face fitting, while the second session was a remote fitting. RP and LP were conducted within a maximum of 2 days and compared regards to T and C levels. Followed by the completion of a questionnaire upon conclusion of the study by programming audiologists.

Results showed no significant differences in T- or C- levels between the two fitting methods; however, there was a statistically significant effect of center.

Possible reasons for the cross-center differences were not detailed by the authors. Overall, the subject and audiologist feedback were positive: 85.5% of subjects were satisfied with the new remote program compared to 93% with the local fitting. Audiologists rated the remote session as equally comparable to face-to-face programming for 64% of the sessions. Speech perception outcome measures were not evaluated in the study.

McElveen et al. (2012) evaluated remote programming for 14 recipients of Cochlear Nucleus System CIs. Preoperative pure-tone averages (PTAs), postoperative aided speech processor PTAs, and pre-and postoperative speech perception scores were compared across two groups (7 programmed face-to-face at the CI center and 7 programmed remotely at a satellite clinic). The groups were matched based on duration of hearing loss and had been programmed by the same audiologist, over a six-to-twelve-month period. Speech perception was evaluated using the Hearing in Noise Test (HINT) sentences and Consonant Nucleus Consonant (CNC) words presented in quiet. This group also had the Nucleus Freedom cochlear implant.

Results revealed no significant difference in preoperative PTAs or speech perception scores obtained at 3- and 6-month intervals between the groups; however, there was a significant difference in postoperative aided PTAs.

The authors attributed differences in postoperative PTAs (which were approximately 10 dB) to differences among the audiologists' programming techniques. As in the Ramos et al. (2009) study, speech perception outcome measures were obtained in the standard face-to-face setting. Similarly, Hughes et al. (2012) examined the reliability of various CI measures performed remotely for 15 Cochlear Nucleus System CI devices.

This prospective study used an A–B–A design (3 remote sites) through 1 remote and 2 in-person visits within 2 weeks. The main outcome measures: Psychophysical thresholds, T and M/C-levels and Speech perception (CNC, HINT). The results (Live versus Remote): Psychophysical thresholds not significantly different T, C, M levels not significantly different, Speech perception significantly poorer for remote.

Luryi et al. (2020) evaluate the effectiveness of remote CI programming via telemedicine. Ten Cochlear nucleus patients were included during the study period. Every subject underwent initial activation and at least the first mapping session in person, then were given the option of tele-audiology follow-up at remote locations. Also, cochlear implant patients underwent regular speech perception testing with AzBio sentence lists. Other data points that were routinely collected at in-person and tele-audiology mapping sessions were threshold levels, comfort levels As a result, there was no significant different found between telehealth and live sessions. AzBio scores and pure tone averages were acceptable in both session methods. Based on IOI-CI scores, patients were very satisfied with their hearing outcomes.

Telehealth is a cost-effective and safe way to deliver post-CI audiologic care, particularly patients who live in remote locations.

Samuel et al. (2014) investigated the effectiveness of remote programming of cochlear implants by testing T and C levels speech perception and audiometric threshold. Twelve Cochlear nucleus patients, aged between 18 and 59 years. The implant model was N24R or N24RE and the speech processors was Freedom SP.

Both (RP) and (LP) were applied on the same day, measuring (T) and (C) levels. Speech perception tests were applied using 65 dBSPL (recorded open context sentences and monosyllables). The patients were submitted to free-field audiometry at 250–8,000 Hz frequencies.

The results showed differences in three electrodesof T levels and one electrode of C levels between RP and LP . No difference was obtained in the speech perception tests and audiometric thresholds in the RP and LP. Slager et al. (2019) assessed forty cochlear Nucleus implant recipients aged 12 years or older, the implant model was CI24R, CI24RE, CI422, and CI500 series, and the sound processor was Nucleus 5 or Nucleus 6. All patients had completed LP session within the 12 months. The main measured: Consonant-Nucleus-Consonant (CNC) word scores and the Speech, Spatial, and Qualities of Hearing Scale-C (SSQ-C) were compared using LP and RP with and without the assistance of a facilitator.

As a result, there is no significant difference was found in CNC word scores and SSQ-C questionnaire outcomes in the three models of implants between LP and RP.

Hughes et al. (2018) used Conditioned play audiometry (CPA) or visual reinforcement audiometry (VRA) to measure thresholds for 35 young children with Nucleus CIs (n = 19 for CPA and n = 16 for VRA). Participants were tested in LP and RP using an AB-BA study design over 2 visits. Noting that using RP for setting upper comfort (C or M) levels have not yet been validated because young children lack the concepts and language to convey loudness percepts.

There was no significant difference in T levels between LP and RP, , The main challenges in RP with young patients were related to the timing of communication between the programming audiologist and the test assistant at the remote site, in addition to proper camera and video monitor placement. The results show that RP can be used successfully to program CI sound processors for young children using standard, age-appropriate testing.

CONCLUSION

Going back to our question, is remote mapping via tele audiology in nucleus CI patients being equivalent to traditional in person programming for all ages?

In fact, the results of the above review show that remote programming for cochlear implant users, with various age groups, is a viable alternative to live programming, Furthermore, remote mapping is a cost-effective, time saving and safe way to deliver post-CI audiologic care. Still, logistical challenges do remain. For example, the timing of communication between the programming audiologist and the test assistant and the availability of a good internet connection.

In the future generation of artificial intelligence, the tele-audiology solutions will take a place in modern practice, in addition to fulfilment of patient acceptance and satisfaction.

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APPENDIX

Table2.

Summary results and review of the above seven articles.

Study	Audiometric threshold		Speech perception (Recognition of HINT sentences + CNC words +AzBio score + open set monosyllable		Average Threshold levels (T Level)		Average Comfort Level (C level)		Results
	LP	RP	LP	RP	LP	RP	LP	RP	
McElveen, et al. (2012)	29 dB HL	17 dB HL	HINT score =80 CNC words =53	HINT score= 83.7 CNC words= 53.3	N/A	N/A	N/A	N/A	No significant differences in HINT and CNC scores between LP and RP
Luryi et al. (2020)	29.4 dB HL	30.6 dB HL	Azbio score = 62%	AzBio score= 71%	124 dB HL	125 dB HL	169 dB HL	170 dB HL	There are no significant differences in T and C levels, as well as Azbio scores. PTA were acceptable in both sessions (LP+RP)

Samuel et al. (2014)	Min= 11.6 dB HL	Min = 16.6 dB HL	Open set= 90%	Open set = 90 %	86.4 dB HL	88.6 dB HL	134. 2 dB HL	135 dB HL	No difference was observed in PTA, open-set word recognition scores as well as T and C levels.
Slager et al. (2019)	N/A	N/A	CNC = 70.5 %	CNC = 72.4 %	N/A	N/A	N/A	N/A	No significantly different mean CNC word scores.
Wesarg et al. (2010)	N/A	N/A	No difference between LP and RP		The mean difference between LP and RP T level over all electrode of -0.53 CL		The mean difference between LP and RP C level over all electrode of -0.51 C		No significant difference in group means speech perception score. Very small differences between the remote and local T and C levels averaged all over electrode. It is not exceeded the minimum clinically significant difference of 2 CL.
Hughes et al. (2018)	VRA = 4.9 nC CPA= 3.1 nC	VRA = 4.9 nC CPA= 2.9 nC	N/A	N/A	N/A	N/A	N/A	N/A	No significant difference in T levels between remote and in-person conditions. It should be noted that the procedures for setting C levels have not yet been validated using remote programming because young children lack the concepts and language to convey loudness percepts
Hughes et al. (2012)	N/A	N/A	CNC word = 70% HINT Score =98	CNC word= 63% HINT Score =95	BAS AL= 145 CL API CAL = 145 CL	BASA L =151 CL APIC AL = 150 CL	BASA L= 198 CL APIC AL = 200 CL	BASA L =200 CL APIC AL = 199 CL	This study found less performance for speech perception in the remote condition, due to the lack of a sound booth, high background noise levels and longest reverberation times. No significant effect of basal or apical T and C levels.

*CNC indicates Consonant-Nucleus-Consonant, VRA indicate visual reinforcement audiometry, CPA indicates conditioned play audiometry, HINT indicates hearing in noise test.

Table3.

Types of nucleus devices and patients age groups.

Number	Study/Author	Number of adult patient/Age	Number of Pediatric or Adolescents patient/Age	Programming Interval	Cochlear ltd Implant type	Cochlear ltd processor type
1.	McElveen et al. (2012)	7 patients post lingually deafened	5 patients 22m-5y	180-365 days	Nucleus freedom cochlear implant	Not specify
2.	Luryi et al. (2020)	10 patients	-	(587 and 735 days)	Cochlear Nucleus	Not specify
3.	Samuel et al. (2014)	12 patients (18-59 years)	-	1020 days	CI24R CI24RE	Freedom sound processor
4.	Slager et al. (2019)	27 patients (21 -88 years) Mean= 45 years	13 patients (12-21yaers)	365 days	CI24R CI24RE CI422 CI500	Nucleus 5 Nucleus 6
5.	Wesarg et al. (2010)	54 patients (18-56 years old)	13 patients	732 days	CI24R CI24M CI22M	Freedom Esprit 3G Sprint ESPrit
6.	Hughes et al. (2018)	-	35 patients	365 days.	Cochlear nucleus	Not specify
7.	Hughes et al. (2012)	15 patients (Adults & pediatrics)		14 days (ABA design) all three sessions were completed within an average of 14 days (range: 2 54 days between the first and last visit.	CI24M CI24RE CI512	3G Freedom Nucleus 5