Published in final edited form as:

Otol Neurotol. 2016 December ; 37(10): 1466–1474. doi:10.1097/MAO.0000000000001236.

The Role of Telemedicine in Auditory Rehabilitation: A Systematic Review

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Abstract

Objective—The purpose of this study was to assess the feasibility and effectiveness of live telemedicine applications in hearing amplification and cochlear implantation.

Data Sources and Study Selection—A systematic search was performed in PubMed, MEDLINE, PsychINFO, CINALH, and Web of Science to identify peer-reviewed research. Inclusion criteria were titles containing words from the search terms (1) audiology, otolaryngology, and hearing impairment, (2) rehabilitative methods, and (3) telemedicine. Exclusion criteria were 1) non-English articles, and 2) non-original research.

Data Extraction and Synthesis—Twelve eligible studies were identified. The studies employed a prospective design in nine of the articles and retrospective case series in three. The use of telemedicine for the provision of cochlear implant services was examined in eight of the articles and with hearing aids in four of the articles. The types of services include intraoperative cochlear implant telemetry; implant programming and assessment of electrode-specific measures and speech recognition after implantation. Hearing aid programming and remote gain assessments were also reported. Many studies assess patient and provider satisfaction along with encounter time comparison. The studies occurred from 2009–2014 and took place in seven countries.

Conclusions—This review examined the feasibility of remote telemedicine connection to provide in auditory rehabilitation services through hearing aids and cochlear implants. There are significant concerns regarding Internet bandwidth limitations for remote clinics. There is a paucity of research examining reimbursement and cost-effectiveness for services. Further prospective research investigating cost-effectiveness and bandwidth limitations is warranted to assess long-term sustainability of remote audiological rehabilitative service delivery.

Keywords

Telemedicine; Auditory rehabilitation; Cochlear implantation; Hearing aids; Systematic review

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Disclosures: The authors have no other financial relationships or conflicts of interest to disclose pertaining to the manuscript.

INTRODUCTION

Approximately 360 million people worldwide have disabling hearing loss.¹ The prevalence of hearing loss is greatest in developing countries, where access to hearing healthcare is limited.² Hearing loss is associated with multiple adverse developmental, social, occupational, and economic consequences.¹ Efforts to improve the hearing of the 360 million affected through the provision of hearing screening and rehabilitative services has been a challenge due a lack of experienced hearing healthcare providers and limited access to existing providers.¹ Developing countries face shortages of providers with some countries facing a ratio of 0.5–3.4 million people per hearing healthcare specialist.³ There are limited resources for screening and rehabilitation of hearing loss in developing countries and many hearing programs require extensive external financial and technical support.^{4,5} Developed countries also face the challenge of effective and efficient delivery of care to vulnerable populations, such as rural residents.^{6–8} The barriers to healthcare access for these vulnerable individuals include the lack of professional healthcare providers, lack of health insurance coverage, distance and transportation, low health literacy, and social stigma and privacy issues.⁹

Hearing rehabilitation, through the use of hearing aids and cochlear implants, is effective in improving communication and quality of life; however, the uptake in use of these devices is poor.^{10–12} In one study, 72% of adults diagnosed with a hearing loss reported no desire to pursue hearing aid amplification to treat their hearing loss.¹⁰ Approximately 1.2 millions patients with severe hearing loss are likely candidates for CI with in the US; however, the utilization rate of cochlear implants is only 5%.¹³ Awareness of cochlear implantation and its benefits is low among the general population and among health-care professionals.^{14,15} There is a significant shortage of audiologists who remain in the field after completion of training, which is projected to affect access to hearing healthcare in future.¹⁶ The presence of disparities in diagnostic and intervention services result in some socioeconomic groups being at a high risk of becoming lost to follow-up.^{17–19} The process of obtaining aural rehabilitation may be complicated for some vulnerable populations, such as the elderly, and compliance with the plan of care significantly impacts auditory outcomes.²⁰

Telemedicine is the transmission of health-related services and information by means of telecommunication technology and has been recognized as a valid and useful tool to deliver care for those in rural and underserved areas.²¹ The use of telemedicine in hearing healthcare is relatively new and the applications include patient education and diagnostic services.^{21–25} Services that may not be available within a remote area can be provided safely, efficiently, and effectively through remote telemedicine connection. Telemedicine has the potential capability to connect hearing specialists, such as audiologists, with patients with hearing loss in remote locations who may otherwise be separated by geographical and economic barriers. The delivery of hearing healthcare to remote areas goes beyond diagnostic testing and education of patients and includes fitting and maintaining hearing aids and cochlear implants, which is a rapidly and promising area of telemedicine. The objective of this study was to assess the feasibility and effectiveness of application of telemedicine in

the provision of live hearing rehabilitative services through the fitting and maintenance of hearing aids and cochlear implants.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist was used to guide to perform this systematic review.²⁶ This system utilizes an evidence-based minimum set of items for reporting in systematic reviews. These elements include a clearly formulated question and explicit methods to identify, select, and critically appraise relevant research. Live auditory rehabilitation via telemedicine involving hearing aid amplification and cochlear implant rehabilitative services were the focus of this systematic review.

Search Strategy

To perform a systematic review of telemedicine applications for hearing rehabilitative services, we first utilized The National Library of Medicine's (NLM) medical subject heading (MeSH) browser in expanded concept view to identify all relevant MeSH indexed search terms.²⁷ In attempt to capture articles inclusive of the study objective, all concept one-level MeSH terms and subsequent narrower entry terms associated with (1) audiology, otolaryngology, and hearing impairment, (2) rehabilitative methods, and (3) telemedicine were identified. Once these terms were identified, an overarching search string was created. The search was performed in June 2015. Additionally, a search including "teletherapy" was performed and yielded no additional articles. Figure 1 lists terms utilized in the search string as well as the algorithm for inclusion/exclusion.

An initial overarching search was conducted in PubMed, utilizing the MeSH search string. [All Fields] was employed for assurance that all relevant articles including the search criteria were identified through the search so not to limit where the MeSH indexed terms were captured (as indexed, in title and in body of article). Searches were limited to English articles published in the last thirty years (1985–2015). Next, searches using the same terms were conducted in MEDLINE, PsychINFO, CINALH, and Web of Science.

Data Extraction

A full-text review of all eligible articles was completed and content of articles based on the objectives of the study was extracted and organized into tables. Considering the focus on hearing loss rehabilitation, articles using telemedicine for hearing screening, diagnosis, use of asynchronous telemedicine, and articles lacking original research studies were excluded. To further expand the search, the references from each of the reviewed studies were examined to identify other pertinent studies to be included in this review.

RESULTS

Search Results

The initial search yielded a total of 772 articles. 528 articles remained after duplicates were removed. After scanning titles and abstracts, 501 articles were excluded due to not meeting

the study criteria of hearing impairment, rehabilitative methods (hearing aids and cochlear implants), and telemedicine. A full-text review and scan of the references of the twenty-seven remaining articles was completed. Twelve of the twenty-seven articles met the inclusion criteria and were eligible for systematic review. The studies employed a prospective design in nine of the articles and retrospective case series in three articles. The use of telemedicine for the provision of cochlear implant services was reported in eight of the articles and with hearing aids in four of the articles. Five of the studies administered questionnaires to obtain subjective feedback. The studies occurred from 2008–2014 and took place in eight countries: Italy, Sweden, Russia, United States, Brazil, Spain, and Australia. See Table 1 for a summary of the twelve articles included. The benefits, limitations, and other considerations for delivery of live hearing healthcare through telemedicine from this review are summarized in Table 2.

Cochlear Implant Studies

Remote interface with cochlear implants can occur at different time points in the delivery of cochlear implant care. Twelve studies were identified that present the feasibility of remote delivery of CI care. The themes identified in the reviewed cochlear implant literature are centered on the nature of clinical services provided through remote connection and include intraoperative implantation telemetry, device activation and programming, and the effect of programming venue on patient outcomes. Intraoperative telemetry is the initial electrophysiological assessment of implant function and neural response to electrical stimulation. This telemetry often utilizes an audiologist being present in the operating room to complete the assessment. Intraoperative CI telemetry through remote connection has been reported in only one paper and the conclusion of this study was that this method, although not directly beneficial to the patient, was significantly timesaving for audiologists in the setting of a densely populated urban area where the surgery center is geographically separated from CI audiologist.²⁸ Furthermore, this study concluded that intraoperative telemetry can be time consuming due to travel to and from the surgery center, equipment set-up, and testing/troubleshooting; while remote testing allowed the audiologist to remain in the clinical office and required nine minutes of time compared 93 minutes when in person testing was performed. Operating room staff or physicians performed the set-up of the on-site computer, which took some training and troubleshooting to address technical difficulties.

Cochlear implant activation and programming was also a major theme identified in the literature and was reported in five manuscripts. These studies involved programming cochlear implants remotely, with or without comparison groups, and reported a variety of outcomes that included amount of time required for programming, audiologist and patient satisfaction with remote programming, and objective hearing outcomes following programming methods. Contrasting study designs provides key differences in these reports. These studies reported similar clinical setup with an assistant, patient, and testing equipment/computer at the remote site with the audiologist at the primary site. The programming was performed through an Internet based connection (of a variety of software programs) to the testing computer in which the audiologist was able to control. The assistant at the remote site facilitated the programming by making the appropriate hardware

connections and instructing the patient. Verbal instructions were given to the patients by the audiologist through telephone, live video, or both. Compromise of audio or video quality between the provider and the patient was reported in all studies but this was infrequent and no adverse events were reported. Two case series provided some preliminary data regarding the possibility of remote programming and provider/patient satisfaction; however, they reported no objective measures of programming. McElveen et al²⁹ assessed the feasibility of remote programming in the United States with a retrospective review of seven patients who underwent remote CI activation over 250 miles from the audiologist. The authors compared the outcomes with seven different CI patients who were activated and programmed in person. There was no within-subject comparison of the programming methods. All programming sessions were performed successfully without any adverse events. Although inadequately powered for determining non-inferiority, this study reported that post-programming hearing testing results were similar between groups. Device activation and programming was successfully performed with no signal corruption or power surges during the process. No objective device impedance or programming measures were reported; however, pure tone average, CNC, and HINT scores were obtained in-person on all participants and the mean scores were similar between groups. They did report video signal interruption related to the remote signal router but was rectified and programming was not affected. In addition, audiologist time commitment was reported as being comparable; however, this was not quantified. Kuzovkov et al³⁰ conducted a multi-national prospective case series in 26 remotely programmed CI patients. Although this study lacked a comparison group, serial measurements, and objective measures, the programming was reported as feasible and providers and patients were largely satisfied with remote programming.

Prospective crossover study designs are utilized consistently in this area of remote CI programming research. Eikelboom et al³¹ reported a prospective crossover study comparing remote and in-person programming with 11 established CI patients. The programming was performed at the same physical location but in different rooms. Electrode impedances, maximum comfort levels (MCL), loudness balancing, Ling six sound test scores, open-set sentences scores, and patient CI map preference were obtained for each programming session and the results were not significantly different between programming methods. There was a significant difference in the mapping time with remote mapping requiring an additional 5–10 minutes. Minimal technical problems were encountered; although, patients and audiologist reported lack of synchronization of audio and video and marginal sound quality. Ramos et al³² reported a prospective crossover study in five established CI patients and found no significant difference in electrode most comfortable stimulation levels (for three electrodes), neural response imaging, and auditory performance between remote and in-person cochlear implant maps. This study was performed with bi-directional audio interface but only uni-directional video connection. Delivery of uncomfortable sound stimuli occurred twice, which was resolved with an immediate stop of stimulation. There were some inconsistencies of audio connection reported by the patient and remote assistant. A multicenter prospective study conducted by Wesarg et al³³ who performed a similar crossover study involving 69 established or newly-implanted CI patients. This study recruited from multiple centers and included 13 pediatric patients as young as one year old. Implant map comfort and threshold (C and T) levels were obtained and were not statistically

significantly different between programming methods. The remote programming was more time consuming than in-person. Almost 40% of patients reported difficulty in communication with the audiologist during the remote session. Most audiologists reported the remote programming setup to be acceptable. This study raised the concern of the amount of bandwidth of the remote connection and the potential effect on implant programming.

The environment in which CI programming occurs and the connection method has the potential to affect the actual programming of the CI and hearing testing outcomes. Centers that provide remote-hearing services may lack sound treated booths, which could influence the hearing testing results of patients with hearing loss and could influence the programming of cochlear implants. Within the US, one group has reported 2 studies that investigate remote testing and programming in “real world” scenarios in CI patients.^{34,35} Hughes et al³⁴ reported a prospective crossover study using a repeated measures (ABA) design comparing the clinical measures and subjective experiences of twenty-nine pediatric and adult cochlear implant users with in-person and remote visits. Participants all had at least one year of experience with cochlear implant use. Five experimental clinical measures were collected including electrode impedance, ECAP thresholds, psychophysical thresholds, programming levels, and speech perception. A questionnaire was delivered at the final visit to examine the subjective experience of the participant. A sound proof booth was utilized at the primary site but quiet conference rooms were selected at the remote sites to mimic a real-world clinic scenario. This study found no significant differences among electrode-specific measures between the primary and remote sites except with apical C-Levels. Poorer measures of speech perception were found at the remote sites and likely due to the lack of a soundproof booth and higher background noise levels. Subjective feedback gleaned from questionnaires found the efficiency of test procedures, quality of test room, appointment check-in process, and ease of communication to be significantly worse at the remote test site compared to the primary site. The commute time to the remote site was shorter than the primary site and most participants felt that they would take advantage of a remote programming site. This same group investigated the effect of acoustic environment and different remote testing systems on speech perception in cochlear implant recipients.³⁵ This study attempts to replicate remote teleaudiology practice settings within a large research center. Sixteen adult and pediatric CI patients were recruited to undergo sound field speech perception testing in a soundproof booth and a quiet testing setting. A Polycom (San Jose, California) videoconference remote testing system was compared with a custom-made hybrid system developed to eliminate bandwidth restriction and audio compression. The hybrid system utilized remote administration of speech testing through high quality audio output at the testing site. Speech testing results in both quiet and noise were better in the sound treated booth environment versus a conference room setting. The hybrid testing system provided better outcome of speech perception testing in noise compared with the Polycom system; however, this effect was not seen during speech testing in quiet.

Hearing Aid Studies

Hearing aid services, such as fitting, device testing, and counseling, can also be provided through telemedicine. Four studies were identified which provide feasibility data for remote delivery of hearing aid care. These studies reported that remote hearing aid care provides

similar outcomes and patient satisfaction when compared to in-person delivery of care. All studies reported pilot data in single country settings. Campos et al²³ used a randomized prospective trial design to assess both quantitative and qualitative measures surrounding remote versus in-person hearing aid fitting, verification, and counseling in 50 hearing aid candidates. Assessments included measurements of the real ear insertion gain (REIG), speech reception via the hearing in noise test (HINT), time to complete procedures, and results from the International Outcome Inventory for Hearing Aids (IOI-HA). One month following the in-person or remote assessment, hearing aid use was determined through data logging. Real ear measurements were similar between the remote and in-person groups. A greater amount of time was required for remote hearing aid programming and verification, but there was no difference in time involved in counseling. There was no difference in HINT scores, IOI-HA, and hearing aid usage between groups. Similarly, another crossover prospective trial investigated programming with follow-up probe microphone measurements in remote versus in-person settings in 60 hearing aid users.³⁶ No significant difference was encountered between these two testing settings.

Providing hearing aid services remotely to resource-limited areas is an important theme that was outlined in the literature as well. Penteado et al²⁴ reported three successful cases of remote hearing aid fitting between a large urban academic center and a smaller healthcare center in a resource-limited region of Brazil. Although no objective outcomes or comparisons were provided, this report provides an explanation of the process and value of providing teleaudiology services and educating local audiologists within a rural region with a lack of hearing specialists. Pearce et al²⁵ also reported a case series of 5 patients from remote locations in Australia receiving a variety of hearing aid-related services via telemedicine connection. These clinical scenarios describe video-otoscopy, diagnostic hearing testing, discussion of hearing aid options, hearing aid programming, probe measurements of fitting verification, hearing aid adjustments, and counseling of hearing aid use and care.

DISCUSSION

Hearing loss is a significant public health issue globally and is ranked the twelfth leading cause of the world-wide disease burden and ranks third in terms disability-related loss of years of health.^{1,37} There is an expanding demand for hearing healthcare but very limited means to open access to care or increase the numbers of providers.³ Hearing loss is more common among adults living in rural communities and timely diagnosis and rehabilitation is complicated in remote areas by limited access to hearing healthcare professionals.^{38,39} Connecting with patients in remote areas can be challenging; however, the expanding availability of cellular phones and the Internet may open new doors to healthcare access.⁴¹ Limited access to healthcare is a pressing issue in Africa, yet 700 million people have cellular phones and there is rapid expansion of telephone Internet access through the whole continent of Africa.^{42,43} Mobile phone hearing screening tools have the potential to expand care into developing countries and remote areas of developed countries.⁴⁴ Video conferencing with high-resolution video through phone, tablet, and other electronic devices is ubiquitously utilized for personal and social connections and represent tools to delivery hearing healthcare services. Accuracy, clinical validity, utility, confidentiality and network

security are a few concerns among others to the delivery of healthcare services through such devices.

This systematic review demonstrates multiple studies that have investigated the delivery of rehabilitative hearing healthcare in a variety of settings internationally. These studies reported that programming of cochlear implants and hearing aids could be performed effectively and efficiently in a small number of subjects.^{29–35} No serious adverse events were encountered; however, degradation of audio and/or video quality in the communication link impaired interactions between providers and patients.^{31–34} In many of these studies, the services that we offered remotely were not available in the area the patient was receiving care. Furthermore, sound treated testing environments and high-fidelity equipment is necessary to adequately assess patient hearing function in these remote locations. Several of the studies were involved multinational collaboration and may increase the generalizability of the research findings.^{30,33} These studies are limited by small numbers and primarily represent pilot data. Remote cochlear implant and hearing aid programming and device assessment was consistent with in-person testing in the studies included in this review. Very few problems or complications in the programming component were reported and essentially no serious safety concerns were raised. Results of speech perception testing were dependent on the testing environment with soundproof settings being superior. Otolaryngology and audiology practices with satellite clinics within rural areas may lack the resources and space for audio booths. The delivery of teleaudiological services in non-hearing center settings could also be compromised by the lack of sound treated booths. Sound field speech testing outcomes are also superior when delivered through high quality audio equipment controlled by the primary center but present at the testing site. This may require additional cost and set-up of a remote site to provide comprehensive services. Limited bandwidth and lack of high-speed Internet connection in some remote locations could potentially prevent the deliver of some services. The value of an assistant at the remote site is immense in this scenario as communication with patients with hearing loss could be severely hampered with poor audio and video output. There is a role for other communication methods with patients through remote connection either through printed material or through a word processor at the testing site. Furthermore, the assistant can be involved in a variety of task including patient intake, manual connection of hardware to patients or patients' devices, monitor the safety and comfort of patients, and troubleshooting technical complications. The key role of that these assistants play in delivery of telemedicine was only a minor theme in the studies of this review.

Implementation of teleaudiology services is complicated by a number of factors. Although the aspects of licensure and reimbursement were not addressed in the studies reviewed, these factors may represent a barrier to the practical delivery of telemedicine services and these topics represent areas for further research. Within the United States, licensure to provide services remotely differs widely within different regions and across international borders. Licensure is complicated within the United States and few states provide reciprocity in licensure, which may restrict the region of delivery of teleaudiological services. Implementation of telemedicine in audiology has been progressive in some American government funded health systems, such as the United States Veterans Affairs systems; however, this poses a challenge for providers to deliver care across state borders to other

regional centers.⁴⁵ Recent legislation within the US seeks to expand licensure to other states while providing telemedicine care within federal healthcare systems (H.R. 2001 Veterans E-Health & Telemedicine Support Act and H.R. 3081 TELEmedicine Act of 2015).^{46,47} There are also vast differences in reimbursement of teleaudiological services between different insurers. Each insurance carrier sets their own standard on coverage for services and determining these nuances could be quite challenging. There are no protocols or standards on telemedicine reimbursement. Within the US, forty-four states provide reimbursement for live telemedicine delivery of care, fifteen states have developed legislation regarding reimbursement from private insurance carriers.⁴⁸ According the American Academy of Audiology there are 20 states which mandate insurance coverage for care delivered through telemedicine; however, government funded insurance programs (i.e. – Medicare) do not reimburse audiologists or speech pathologists for telemedicine services.⁴⁹ The Medicaid programs in some states reimburse some services through telemedicine for audiologist when appropriate billing (GT modifier) and justification is provided.⁴⁹ There is a great need to more adequately quantify the cost-effectiveness of audiological telemedicine services worldwide. The studies included in this review provided no meaningful assessment of cost analysis thus conclusions from this review are limited. A recent systematic review of telemedicine applications in the delivery of care in communication disorders reported that of 103 studies, only 12.6% reported on cost-effectiveness.⁵⁰ Full assessment of cost-effectiveness requires both economic and outcomes analysis and there is a paucity of evidence in the literature. None of the reports within this review addressed this topic. Further research is also needed internationally to address implementation and dissemination of teleaudiology into remote areas. The application of these services could open the door to rehabilitation to many more patients who may not otherwise able to access care.

There are multiple limitations of this review as well as the articles included in the review. In spite of thorough search criteria, it is possible that relevant articles were excluded from this review. A number of the studies involved in small numbers of participants without comparison groups and served as feasibility or pilot studies. Conclusions drawn from this systematic review are limited given that a meta-analysis could not be performed due to the lack of higher-evidence. Comparisons between studies were difficult due to the diversity of articles and the lack of standard outcome measures across articles. In spite of these limitations, this review indicates that telemedicine delivery of auditory rehabilitation is feasible and will likely play a meaningful role in the future of healthcare access.

CONCLUSION

Telemedicine has been reported for hearing rehabilitative services for patients with hearing loss, specifically hearing aids and cochlear implants in 11 countries and has primarily been utilized to provide care in remote rural locations lacking specialty care. This review demonstrates the potential and challenges of telemedicine to provide in auditory rehabilitation services and outcomes are similar to in-person services. There is a paucity of research examining reimbursement and cost-effectiveness for these services. Further prospective research investigating cost-effectiveness and bandwidth limitations is warranted to assess long-term sustainability of telemedicine.

Acknowledgments

This work was supported by the American Academy of Otolaryngology – Head and Neck Surgery Foundation (Triological Society Career Development Award) (MLB) and National Institute of Deafness and Other Communication Disorders (1K23DC014074-01A1)(MLB). MLB is a member of the Surgical Advisory Board of Med El Corporation.

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Figure 1.

Preferred reporting items for systematic review and meta-analysis algorithm for the use of telemedicine in rehabilitation of hearing loss

Table 1

Results from systematic review

Author	Journal/Year	Countries	Study Type	Study Population	N	Level of Evidence	Field of Rehabilitation	Software	Hardware/ Connection	Outcomes
Elkelboom ³¹	Journal of Telemedicine and Telecare 2014	Australia	Prospective Crossover	Adults	11	2b	CI Programming	Custom software, Advanced Virtual COM port	Laptop, videocamera, VPN	MCLs, Ling Six test, Open-set questions, Subjective Feedback (Subject and Provider), & Time
Kuzovkov ³⁰	Acta Oto-Laryngologica 2014	Italy, Sweden, & Russia	Prospective Case Series	Adults & Children	26	4	CI Programming	Not reported	Laptop, Voice over IP	Subjective Feedback (Subject and Provider), & Time
Hughes ³⁴	Journal of Speech, Language, and Hearing Research 2012	United States	Prospective Crossover	Adults & Children	29	2b	CI Programming, Speech Perception	Visual Concert	Laptop, Polycom VSX	Impedance, ECAP thresholds, psychophysical thresholds, programming levels (T/M/C Levels), CNC, HINT, BKB-SIN, & Subjective Feedback (Subject)
Goehring ³⁵	Journal of Speech, Language, and Hearing Research 2012	United States	Prospective Crossover	Adults & Children	16	2b	CI, Speech Perception (Environment & Technology)	Visual Concert, Custom software with Open Sound Control	Laptop, Polycom	SPLs and reverberation measures of environments, CNC, HINT, & BKB-SIN
McElveen ²⁹	Otology & Neurotology 2010	United States	Case Series	Adults & Children	14	4	CI Programming, Speech Perception	Virtual network computing	Desktop, Polycom V700, VPN	Pre-Op. & Post-Op. PTAs, HINT & CNC
Wesarg ³³	Acta-Otolaryngologica 2010	Germany, Poland, Spain, Greece, Switzerland	Prospective Crossover	Adults & Children	70	2b	Cochlear Implant Programming	GoToMyPC Skype	Laptop, Polycom, VidConference	C & T Levels, Subjective Feedback (Subject and Provider)
Ramos ³²	Acta Otolaryngologica 2009	Spain	Prospective Crossover	Adults	5	2b	Cochlear Implant Programming	Skype, Ultra VNC	Laptop	ML Levels, NRI, Auditory Progress (threshold evaluations, FFWTA & DOPT), and Subjective Feedback (Subject & Provider)
Shapiro ²⁸	Otology & Neurotology 2008	United States	Case Series	N/A	8	4	Intraoperative CI telemetry	Tridia VNC	Laptop, Speaker phone	Testing times for remote and in situ monitoring
Campos ²³	J Soc Bras Fonoaudiol 2012	Brazil	Prospective Randomized	Adults	50	1b	Hearing Aid Fitting	Polycom PVX	Desktop	REIG, HINT, IOI-HA, Hearing aid usage

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Author	Journal/Year	Countries	Study Type	Study Population	N	Level of Evidence	Field of Rehabilitation	Software	Hardware/Connection	Outcomes
Ferrari ³⁶	Journal of Telemedicine and Telecare 2009	Brazil	Prospective Crossover	Adults	60	2b	Probe Microphone Hearing Aid Measurements	Polycom PVX	Desktop	REUR, REAR, and REIG
Penteado ²⁴	Int. Archives of Otorhinolarygology 2012	Brazil	Case Series	Adults	3	4	Hearing Aid Fitting	Skype, Anyplace Control, AdaptEASY	Desktop	Subjective feasibility reporting of 3 remote hearing aid fittings
Pearce ²⁵	The Australian and New Zealand Journal of Audiology 2009	Australia	Case Series	Adults	5	4	Hearing aid assessment, adjustment, and Counseling	pcAnywhere	Laptop, Video Conferencing Units	Subjective feasibility reporting of 5 case studies (remote fitting, video-otoscopy, REAR)

MCLs = Maximum comfort levels; ECAP = Evoked compound action potential; Psychophysical thresholds= experimentally-based behavioral thresholds; M-Level = most-comfortable threshold level; C-Level = upper-loudness comfortable threshold level; CNC = consonant-nucleus-consonant; HINT= hearing in noise test; BKB-SIN = Bamford-Kowal-Bench Sentences-In-Noise; Reverberation measures = time, early decay time, and clarity of speech; PTAs = Pure tone averages; NRI = Neural response imaging; FFWTA = Free field warble tone audiometry; DOWT = Disyllabic open words test; REIG = real ear insertion gain; IOI-HA = International Outcome Inventory for Hearing Aids; REUR = Real ear unaided response; REAR = Real ear aided response.

Table 2

Summary of Reported Benefits and Limitations of Telemedicine in Auditory Rehabilitation

Cochlear Implantation Telemetry, Activation, and Programming					
Benefits		Limitations		Other Considerations	
<ul style="list-style-type: none">• Time savings in intraoperative telemetry²⁸• Limits travel of patients and providers^{28,29}• Facilitates multinational programming protocols and delivery of care³⁰• Similar clinical implant function parameters and hearing outcomes as in-person programming^{31–33}• No reported serious adverse events^{29–35}• Programming can be performed without sound treated booths^{34,35}		<ul style="list-style-type: none">• Surgical staff responsible for intraoperative equipment and connection²⁸• Connectivity complications^{31–34}• Difficulty in communication between patients and providers^{31–34}• Potential for overstimulation³²• Appointment times may be increased^{34,35}• Inferior speech testing results when performed outside of audio booths³⁵		<ul style="list-style-type: none">• Speech testing results are superior when high fidelity equipment is utilized at the remote site (controlled by a provider over internet connection)³⁵• Customized systems provide superior remote speech testing results³⁵	

Hearing Aid Services Fitting and Maintenance					
Benefits		Limitations		Other Considerations	
<ul style="list-style-type: none">• Similar patient satisfaction outcomes with in-person delivery of care²³• Can be used for fitting, verification, and counseling²³• Similar gain measurements with in-person programming²³• Similar appointment times for counseling³⁶• Similar hearing aid useage, speech testing, and subjective improvement with in-person care³⁶		<ul style="list-style-type: none">• Longer appointment times for programming and verification³⁶		<ul style="list-style-type: none">• Important tool to educate rural audiologists²⁴• Successful delivery of care to very rural areas²⁵	