J Am Acad Audiol 30:827–844 (2019)

Clinical Practice Guidelines: Cochlear Implants

DOI: 10.3766/jaaa.19088

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Key Words: cochlear implants, American Academy of Audiology guidelines, best practice guidelines, American Academy of Audiology, Cochlear implant guidelines

INTRODUCTION

Cochlear implants are an increasingly popular treatment for improving access to auditory information for persons with hearing loss. Since their initial approval by the Food and Drug Administration (FDA) in 1984 for use in adults with bilateral profound sensorineural hearing loss, cochlear implant candidacy has expanded as a treatment option for children and individuals with varying degrees of hearing loss. Cochlear implant candidacy is likely to continue to evolve as evidence becomes available, which supports expanding its use for those who do not demonstrate benefit from acoustic amplification alone. As the number of individuals using cochlear implants increases, the need for access to appropriate evidence-based care from audiologists and cochlear implant multidisciplinary teams continues to grow.

Considerable variability in performance outcomes among recipients of a cochlear implant has been well documented in the scientific literature (e.g., Cosetti and Waltzman, 2012; Blamey and Artieres, 2013). A large number of factors, both intrinsic and extrinsic to the user, have been shown to impact postoperative performance with a cochlear implant. Many of these elements are outside the control of the audiologist and care team; however, one factor that can be addressed is access to appropriate services and follow-up care (Mertes and Chinnici, 2006). Although many professionals may be involved in the care and success of recipients of a cochlear implant, audiologists play a large role in diagnosis and counseling regarding hearing loss, providing services for candidacy determination, and delivering appropriate follow-up care to recipients of a cochlear implant. The audiologist will likely have a long-term relationship with their patients who have a cochlear implant, as appropriate follow-up care consists of routine appointments across the recipient's lifetime. Despite the known importance of the audiologist and the services they provide to recipients of a cochlear implant, cochlear implant practice patterns vary widely across audiologists for both adult and pediatric populations (Uhler and Gifford, 2014; Vaerenberg et al, 2014; Hemmingson and Messersmith, 2018). Given the rise in cochlear implantation as an appropriate treatment option for individuals with hearing loss in light of variability in performance outcomes and variability in practice patterns across audiologists, a need for a best practice guideline document was identified.

Goal of the Guidelines Document

The goal of the American Academy of Audiology (the Academy) cochlear implant best practice guideline document was to provide an initial framework of considerations for practicing audiologists for reference when working clinically with children and adults who are considering, or presently using, a cochlear implant. These guidelines consist of a set of statements, recommendations, and strategies to address all aspects of cochlear implant care, beginning with initial preimplantation candidacy considerations and continuing through postoperative follow-up care. The guideline document was divided into the following content sections: (a) Signal processing, (b) Audiological candidacy criteria, (c) Surgery considerations for the audiologist, (d) Device programming, (e) Outcomes assessment and validation, (f) Follow-up schedule, and (g) Care beyond device programming. The objective introduction of each content section is provided in the following text.

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Signal Processing

Cochlear implant signal processing provides the basis for cochlear implant programming and directly impacts the cochlear implant recipient's outcomes with the device. Decisions regarding signal processing are based on the individual's listening needs, abilities, and cognitive considerations; understanding of the physiology and function of the system; empirical evidence; and clinical expertise. These decisions target the goal of enhancing outcomes with the cochlear implant device. Although many aspects of signal processing may stabilize across the time period of using a cochlear implant, these aspects should be considered when changes in performance or device function occur or if the user's listening needs change. An outline of the features of signal processing and how they may apply to cochlear implant programming and performance outcomes is provided in this section.

Rec	Evidence	Source
1)a.	Measurement of impedance telemetry provides information about short and open circuits and contributes to the maximum output of the device, and a timeline of impedance measures contributes to evaluation of internal device function.	Electrical and physical fact; Carlson et al (2010), Goehring et al (2013), Hughes et al (2001)
2)a.	Directional microphone processing should be considered for all patients.	Hersbach et al (2012), Wolfe et al (2012), Wolfe et al (2015c)
2)b.	Full-time directional processing is not necessary and should be used with caution in children	No published evidence available specific to children who use cochlear implants. Well documented in the hearing aid literature. See AAA Pediatric Amplification Guidelines for review.
3)b.	Optimization of stimulus levels is a primary factor contributing to outcomes.	Bauduin et al (2012), Sainz et al (2003)
4)b.	The size of the IDR should be adequately wide to provide optimum speech perception in quiet and noise while providing a sound that is perceived as comfortable by the user.	Cosendai and Pelizzone (2001), Davidson et al (2009), Dawson et al (2007), Holden et al (2011), Holden et al (2007), Santarelli et al (2009), Spahr et al (2007), Zeng et al (2002)
5)a.	Increasing sensitivity may provide improved speech perception performance in quiet, but may result in poorer speech perception performance in sound environments with noise.	Bauduin et al (2012), James et al (2003), Spahr et al (2007)
5)b.	Conversely, decreasing sensitivity may be useful for controlling excessive background noise when necessary.	No published evidence available. Current clinical practice.
6)b.	Cochlear implant recipients may demonstrate a perceptual preference and/or a performance difference across stimulation rates. Determination of the stimulation rate can be based on recipient preference and assessments of benefit.	Arora et al (2009), Balkany et al (2007), Park et al (2012), Vandali et al (2000)
7)a.	Pulse duration should be balanced with the pulse rate and stimulation level to obtain adequate loudness perception for the cochlear implant recipient.	Physical fact; Bonnet et al (2012)
8)a.	Because threshold and comfort levels can be affected by the sound-encoding strategy used, it is important to set the strategy before collecting threshold and loudness levels (EDR).	Physical fact; Bonnet et al (2012), Shapiro and Bradham (2012)
8)b.	Use newer processing strategies, as they have been shown to provide greater flexibility in programming options to optimize patient performance.	Physical fact
8)c.i-8)c.ii.	Typically, monopolarity can allow for lower and more consistent threshold values because of a larger physical separation of active and return electrodes. This allows for interpolation of threshold and comfort-level values of adjacent electrodes not obtained through actual behavioral testing, as well as extending battery life.	Bierer (2007), Pfingst and Xu (2004)
9)c.	More spectral information across channels may lead to improved performance with the device.	Moore (2008), Shannon et al (2004), Zeng et al (2008)

Continued

Rec	Evidence	Source
9)d.	Utilization of virtual channels can increase the number of pitch perceptions and frequency coding realized by the cochlear implant user, which may in turn result in improved performance by the cochlear implant user.	Berenstein et al (2008), Bonham and Litvak (2008), de Melo et al (2012), Donaldson et al (2005), Firszt et al (2007), Koch et al (2007), Landsberger and Srinivasan (2009)
10)a.	Features such as digital noise reduction, wind reduction, and other adaptive signal processing features may prove beneficial for some recipients of cochlear implants.	Dingemanse and Goedegebure (2018), Dorman et al (2017), Honeder et al (2018), Wolfe et al (2015a), Wolfe et al (2015b)

Candidacy Considerations for the Audiologist

The preoperative evaluation is a dynamic and evolving aspect of the implant process. During this process, and through periodic team meetings, cochlear implant team members work together to evaluate outcomes with available technologies to determine if cochlear implantation will likely result in improved hearing for each individual. Candidacy is strongly influenced by the likelihood of improved hearing and evolving criteria. This section will discuss the role of the audiologist in the candidacy process, including aspects of counseling, typical preoperative test battery, and collaboration with other professionals.

Rec	Evidence	Source
1)a.i.2.(a)	Presence of abnormal cochlear anatomy may impact candidacy and predict postoperative outcomes.	Kang et al (2016)
1)a.i.2.(b)	Age at implantation may impact candidacy and predict postoperative outcomes.	Blamey and Artieres (2013), Bruijnzeel et al (2016)
1)a.i.2.(c)	Perinatal problems, such as meningitis, hyperbilirubinemia, and other etiologies associated with sensorineural hearing loss, may impact candidacy and predict postoperative outcomes.	Abdurehim et al (2016), Kang et al (2016), Philippon et al (2010)
1)a.i.2(d)	Duration of deafness may impact candidacy and predict postoperative outcomes.	Blamey and Artieres (2013), Holden et al (2013)
1)a.i.2(e)	Hearing aid use before implantation may impact candidacy and predict postoperative outcomes.	Caposecco et al (2012), Holden et al (2013), Lazard et al (2012)
1)a.i.2.(a)	Prelingually deafened adolescents and adults may benefit from cochlear implantation and should not be excluded from candidacy. Families should be counseled regarding realistic expectations.	Caposecco et al (2012), Klop et al (2007), Leigh et al (2016), Ventry and Weinstein (1982), Zwolan et al (1996)
1)a.i.2.(b)	Children with disabilities in addition to deafness may benefit from cochlear implantation in quality-of-life outcomes and environmental awareness. These groups should not be excluded from candidacy. Families should be counseled regarding realistic expectations.	Cejas et al (2015), Eze et al (2013)
1)a.i.2.(c)	Elderly patients may benefit from cochlear implantation and should not be excluded from candidacy. Families should be counseled regarding realistic expectations.	Wong et al (2014), Yang and Cosetti (2016)
1)a.ii.2.	Audiometric threshold testing is used to determine candidacy, and better preoperative hearing thresholds are associated with better postoperative outcomes in children and prelingually deafened adults.	Chiossi and Hyppolto (2017), De Kleijn et al (2018), Lammers et al (2018)

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Rec	Evidence	Source
1)a.iv.1	Audiologists should perform electroacoustic verification of amplification to ensure appropriate fit to determine the best-aided condition.	Uhler et al (2017)
1)a.iv.2.(a)	If the patient's hearing aid is determined not suitable, adjustments should be made or an appropriate hearing aid must be used for the evaluation.	No published evidence available: current clinical practice
1)a.iv.3.	Speech-perception testing should be performed in the sound field using recorded materials at a level of 60 dBA SPL to reduce variability.	Alkaf and Firszt (2007), Robbins et al (1991)
1)a.iv.4	Speech-perception material should be developmentally and linguistically appropriate. Test materials should be sensitive enough to measure differences in hearing technologies and performance over time.	Tyler et al (2009)
1)b.i.	Test of nonbehavioral auditory function may also be part of the of the test battery, including assessment of the peripheral auditory function and lower brainstem function.	No published evidence available: current clinical practice
1)b.ii.	Test of nonbehavioral auditory function may also be part of the of the test battery, including assessment of the vestibular system. Vestibular disturbances may occur after implantation and should be discussed with the patient before surgery.	Ibrahim et al (2017)
1)c.	Preoperative assessments of subjective performance and quality of life can help to determine communication needs and can later be used to validate postoperative benefit.	Cox and Alexander (1995), Dillon et al (1997), Gatehouse et al (1999), Hinderink et al (2000)
2)a.	A preoperative evaluation by the surgeon to determine candidacy is a routine practice.	No published evidence available: current clinical practice
3)a.i.1.	A speech and language evaluation may be recommended in adult candidacy evaluations and could be considered critical in pediatric candidacy evaluations.	No published evidence available: current clinical practice
3)a.ii.1.	Pediatric cochlear implant recipients are at an educational disadvantage when compared with normal-hearing peers. An educational evaluation can bring valuable educational information to the candidacy process.	Harris et al (2017), Nittrouer et al (2014)
3)a.iii.1.	Because of the increased risk of depression, reduced social engagement, and poorer health-related quality of life in individuals with hearing loss, a psychology and/or social work evaluation may be recommended for adults and children.	Knutson et al (2006), Lin and Niparko (2006), Nordvik et al (2018)
3)a.iii.2.	A cognitive evaluation or cognitive screener should be considered when evaluating older adults.	Roeser and Clark (2008), Shen et al (2016), Ventry and Weinstein (1982)
4)a.	Counseling toward appropriate expectations should be conducted by the audiologist.	No published evidence available: current clinical practice

Surgical Considerations for the Audiologist

Although the surgical procedure is not within the purview of the audiologist, there are a number of issues surrounding surgery of which the audiologist needs to be aware. Knowledge of the procedure will allow the audiologist to guide the patient through the process and understand when to refer concerns to the surgeon. This section will focus on the aspects of the surgical procedure where the audiologist will have an active role.

Rec	Evidence	Source
1)a.	Intraoperative testing, completed in person in the operating room or remotely, can provide valuable information to the audiologist, as well as to the surgeon and family, about the integrity of the device. However, determination of when to use a backup device is unclear in the present literature.	Carlson et al (2010), Cosetti et al (2012), Goehring et al (2013), Mason (2004), Shapiro et al (2008)
1)a.i.1	Telemetry indicates whether or not the device can provide appropriate stimulation.	Cosetti et al (2012), Goehring et al (2013), Shallop et al (1999), Shennawy et al (2015)
1)a.i.1.(a)	Normal impedance values do not imply a full insertion. Rather, this information indicates that electrodes are in contact with an electrically conductive medium.	Goehring et al (2013), Shennawy et al (2015)
1)a.i.1.(b)	Impedance values tend to be at their lowest in the operating room during surgery.	Busby et al (2002), Hughes et al (2001), Shennawy et al (2015)
1)a.i.2.	Short circuits are identified as abnormally low impedance values as designated by each manufacturer.	Physical fact
1)a.i.3.	Open circuits are identified as abnormally high impedance values as designated by each manufacturer.	Physical fact
1)a.ii.1	ECAP can be used as a tool for determining the auditory nerve and device function. Lack of an ECAP threshold does not necessarily indicate that the device is malfunctioning or the auditory nerve is not functioning.	Caner et al (2007), Cosetti et al (2010), Gordon et al (2004b), Grolman et al (2008), Mason (2004), Shennawy et al (2015)
1)a.ii.2	Intraoperative ECAP thresholds do not serve as the best predictor of postoperative settings (i.e., upper stimulation levels). Intraoperative measurements are typically observed at higher stimulus levels than measures obtained postoperatively.	Gordon et al (2004b), Hughes et al (2001), Shennawy et al (2015), Telmesani and Said (2016)
1)a.iii.1	ESRT can be used as a tool for determining device function. Lack of an ESRT threshold does not necessarily indicate that the device is malfunctioning or the auditory nerve is not functioning.	Gordon et al (2004b), Mason (2004)
1)a.iii.2	ESRT can be obtained intraoperatively through the following: (a) change in the static admittance of the middle ear as recorded in the ear canal using an immittance bridge and (b) visual observation of the contraction of the stapedius muscle by the surgeon.	Gordon et al (2004b), Opie et al (1997), Pau et al (2011), Shallop et al (1999)
1)a.iii.c	Intraoperative ESRT measurements do not serve as the best predictor of postoperative settings (i.e., upper stimulation levels). Intraoperative measurements are typically observed at higher stimulus levels than measures obtained postoperatively. Furthermore, intraoperative measurements can be affected by anesthesia dosage.	Caner et al (2007), Crawford et al (2009), Makhdoum et al (1998), Van den Borne et al (1996)
2)a.	Emerging evidence exists for use of intraoperative testing to monitor hearing preservation and acoustic trauma during insertion of the electrode array. Specifically, the use of ECochG during electrode array insertion can provide real-time information regarding cochlear function. Changes in cochlear function observed during surgery may impact outcomes, specifically residual hearing, postoperatively.	
3)a.	Following surgery, patients must have sufficient time for the implant site to heal before initial activation is to occur.	No published evidence available: current clinical practice

Device Programming

Device programming is one of the most critical elements of a recipient's success with a cochlear implant and is heavily influenced by the programming audiologist's knowledge and experience with cochlear implants. This section provides recommendations outlining the possible procedures that can be followed or performed when programming a recipient's cochlear implant after surgery.

Rec	Evidence	Source
1)a.i.	Before the initial stimulation, it can be helpful for the audiologist to obtain a copy of the operative and/or intraoperative monitoring report. The report(s) can provide useful information regarding the number and the integrity of electrodes inserted intracochlearly.	Shapiro and Bradham (2012)
3)a.	Check skin flap (skin between the headpiece and the internal magnet) integrity to ensure no irritation or tissue breakdown.	No published evidence available; current clinical practice
4)a.	Electrode impedances should be measured as frequently as possible, at least during appointments where a change to programming is made, and compared across multiple visits to evaluate any sudden or slow changes in electrode function over time.	Carlson et al (2010), Henkin et al (2003)
4)b.	Electrodes that intermittently present as short or open circuits should be programmed out of the map, as this may be a sign of impending permanent electrode failure. The present literature available regarding the number inactive electrodes required to consider device failure and subsequent revision surgery is unclear.	Carlson et al (2010), Shapiro and Bradham (2012), Zeitler et al (2008)
5)a.	Because threshold and upper stimulation levels can be affected by the processing/coding strategy used, it is important to set the processing/coding strategy before obtaining information used to establish the electrical dynamic range.	Physical fact
6)a.	Establish electrical dynamic range on all or a selected subset of electrodes via psychophysical measurements of threshold (T) and upper stimulation level and/or physiological measurements (i.e., ECAP and ESRT). Some research suggests a measurement of a subset of electrodes is adequate. Common clinical practice varies.	Plant et al (2005)
6)a.i.	Obtaining accurate psychophysical measures of loudness and pitch is likely to improve the recipient's performance with the cochlear implant.	Dawson et al (1997), Shapiro and Bradham (2012)
6)a.ii.1.(b)(i)	If T levels are set too low, the recipient may not be provided with sufficient audibility of soft sounds.	Wolf and Schafer (2011)
6)a.ii.1.(b)(ii)	If T levels are set too high, the recipient may experience a greater level of ambient noise, as well as a restricted EDR.	Wolfe and Schafer (2011)
6)a.ii.2.(a)(i)	Underestimating the upper stimulation levels may negatively impact speech recognition, sound quality, and ability to monitor the sound of one's voice.	Wolfe and Schafer (2011)
6)a.ii.2.(a)(ii)	Overestimating the upper stimulation levels may result in discomfort and aversion to the device, as well as negatively impacting speech recognition and sound quality.	Wolfe and Schafer (2011)
6)b.i.1.(c)	Several studies have shown strong correlations between ESRT and map upper stimulation levels. Findings are mixed in regard to how often ESRTs underestimate, approximate, or overestimate map upper stimulation levels.	Battmer et al (1990), Gordon et al (2004a), Han et al (2005), Hodges et al (1997), Lorens et al (2004), Opie et al (1997), Spivak and Chute (1994)
6)b.i.1.(d)	ESRT may not be measurable in all cochlear implant recipients. Normal tympanometric findings are required.	Battmer et al (1990), Hodges et al (1999), Hodges et al (1997), Lorens et al (2004)

Continued

Rec	Evidence	Source
6)b.i.2.(a)	ECAP thresholds and program stimulation levels are only moderately correlated.	DeVos et al (2018), Polak et al (2005)
6)b.i.2.(b)	ECAP thresholds generally occur within the electrical dynamic range, although they may exceed upper comfort levels for some recipients. ECAP thresholds almost always occur above the behavioral T level. ECAP thresholds, therefore, represent a level that should be audible to the user of the CI.	DeVos et al (2018)
6)b.i.2.(c)	Lack of an ECAP threshold does not necessarily indicate a device malfunction.	Physical fact
7)a.	Programming with equal loudness percepts across channels will likely result in improved sound quality.	Dawson et al (1997), Shapiro and Bradham (2012)
7)b.	Electrodes that are enabled should provide increasing pitch perception as the electrode location progresses from the apical to the basal cochlear place. Electrodes that are reported by the recipient as deviating from this organization and/or those which are not perceived as differing in pitch should be disabled in programming.	DiNardo et al (2010), Fu and Galvin (2002)
8)a.	Go live after establishment of the EDR to ensure comfort and audibility. Informal speech testing, for example, Ling sounds test, should be performed to ensure that the patient has access to various frequencies in the speech domain.	Shapiro and Bradham (2012)
9)a.	When placing programs in the sound processor memory, the most effective program is the one that requires minimal manipulation.	No published evidence available; current clinical practice
9)b.	Progressively, louder programs may be warranted at initial stimulation based on the recipient's initial reaction and acceptance of the device.	Wolfe and Schafer (2011)

Outcomes Assessment and Validation

Outcomes assessment is a critical component of cochlear implant follow-up care. Outcomes assessment allows the audiologist to provide evidence of improved auditory access with a cochlear implant as well as information that can be used to counsel recipients and those involved in the recipient's care. This section will discuss qualitative and quantitative measures that can serve as methods of validation for both adult and pediatric cochlear implant recipients.

Adults

Rec	Evidence	Source
1)a.	Adult cochlear implant recipients should complete measures of speech perception outlined by the MSTB to assess performance outcomes and treatment efficacy.	Minimum Speech Test Battery (MSTB) (2011)
2)a.	Subjective input from the recipient and those who regularly interact with the recipient should also be considered when determining the effectiveness and benefit derived from a cochlear implant.	Damen et al (2007), Hawthorne et al (2004), MSTB (2011), Mo et al (2005)
3)a.	Audiologists must consider what assessment tools are most appropriate on a case-by-case basis.	Gifford et al (2008)
4)a.	Poor performance during validation testing in the sound booth warrants further investigation into potential factors that may be impacting performance with a cochlear implant.	Firszt et al (2004), Holden et al (2013)

Pediatrics

Rec	Evidence	Source
1)a.	Pediatric cochlear implant recipients should complete measures of speech perception outlined by the PMSTB to further assess performance outcomes and treatment efficacy.	Uhler et al (2017)
2)a.	Subjective input from the recipient and those who regularly interact with the recipient should also be considered when determining the effectiveness and benefit derived from a cochlear implant.	Meinzen-Derr et al (2007), Obrycka et al (2017), Punch and Hyde (2011), Warner-Czyz et al (2009)
3)a.	Audiologists must consider what assessment tools are most appropriate on a case-by-case basis.	Uhler et al (2017)
4)a.	Poor performance during validation testing in the sound booth warrants further investigation into potential factors that may be impacting performance with a cochlear implant.	Davidson et al (2009)

Follow-Up Schedule

Regardless of age, accurate mapping of the electrical dynamic range is a main contributor to postoperative performance. Frequent appointments are necessary in the first year following activation of the cochlear implant to optimize programming and maximize audibility. Continued device management, monitoring of surgical site, and monitoring of progress with the device are necessary to ensure auditory access and appropriate fitting across time. This section will discuss the typical timeline of follow-up care for both adult and pediatric recipients of a cochlear implant.

Rec	Evidence	Source
1)a.	Follow-up schedule for children for the first year of device use. a. Initial activation: typically one to four weeks postoperatively, b. One week after initial activation, c. One month after initial activation, d. Three months after initial activation, e. Six months after initial activation, f. Nine months after initial activation, g. 12 months after initial activation.	Bradham et al (2009), Hemmingson and Messersmith (2018), Shapiro and Bradham (2012), Uhler and Gifford (2014), Vaerenberg et al (2014)
1)b.	For children, the follow-up schedule after the first year of device use should be dependent on the progress the child has made with the device and the caregiver's comfort and skill in maintaining the equipment.	Shapiro and Bradham (2012)
1)c.	For children who are not reliable in reporting sound quality or for those whose caregiver has not developed skill in maintaining equipment, follow-up appointments may be warranted every three months.	Hemmingson and Messersmith (2018), Uhler and Gifford (2014)
1)d.	Children who are reliable in reporting sound quality and whose caregiver has developed competence in maintaining the equipment may be seen for follow-up appointments less frequently. For example, biannually (i.e., every six months) for school-aged children or annually for adult-like children.	Hemmingson and Messersmith (2018), Shapiro and Bradham (2012), Uhler and Gifford (2014)

Continued

Rec	Evidence	Source
2)a.	Follow-up schedule for adults for the first year of device use. a. Initial activation: typically one to four weeks postoperatively, in accordance with recommendation and approval of the surgical team, b. One week after initial activation, c. One month after initial activation, d. Three months after initial activation, e. Six months after initial activation, f. 12 months after initial activation.	Shapiro and Bradham (2012), Vaerenberg et al (2014)
2)b.	For adults, the follow-up schedule after the first year of device use should be dependent on the progress the individual has made with the device. For most adults, follow-up appointments can occur biannually (i.e., every six months) or annually.	Shapiro and Bradham (2012), Vaerenberg et al (2014)
3)a.	For both children and adults, additional programming sessions should be scheduled if certain changes in the patient's auditory responsiveness or speech production occur.	Shapiro and Bradham (2012)

Components of Follow-Up Appointments

Through continued device management, adequacy of device fitting and benefit with the device can be tracked and necessary changes to device fitting can be made as needed. Additional components included in the ongoing care of an individual with a cochlear implant may include informational and adjustment counseling, connection with educational and vocational rehabilitation resources, development of self-advocacy skills, and assurance of patient support for continued cochlear implant use. Combined, these components of follow-up appointments contribute to the benefit recipients gain from the use of their cochlear implant. This section will discuss the typical procedures initially discussed in the programming content section and where these procedures may be included in follow-up appointments across time for both adult and pediatric recipients of a cochlear implant.

Rec	Evidence	Source
1)a.	Assurance of equipment function is critical for device use and benefit.	No published evidence available; current clinical practice
2)a.	A measure of telemetry/impedance should be completed at most follow-up appointments, particularly at those where changes are made to device programming.	Carlson et al (2010), Shennawy et al (2015), Vaerenberg et al (2014), Zeitler et al (2008)
3)a.	Conduct ongoing evaluation/assessment of the individual's electrical dynamic range to ensure appropriateness as well as program optimization.	Hemmingson and Messersmith (2018), Vaerenberg et al (2014)
3)b.	Electrical thresholds and upper stimulation levels determined based on the patient report of loudness can fluctuate, particularly during the first year of cochlear implant use.	Raghunandhan et al (2014), Shapiro and Bradham (2012)

Continued

Rec	Evidence	Source
3)c.	Appropriateness of the electrical dynamic range can be evaluated through multiple means. The user's behavioral reports of threshold and loudness, physiological measures, and outcome and validation measures should all contribute to the determination of appropriateness of electrical dynamic range across follow-up appointments.	Gordon et al (2004b), Greisiger et al (2015), Han et al (2005), Hughes et al (2001), Raghunandhan et al (2014), Walkowiak et al (2011)
4)a.	Optimization of programming should include performance of loudness balancing and pitch ranking.	Dawson et al (1997), DiNardo et al (2010), Fu and Galvin (2002), Shapiro and Bradham (2012)
4)b.	Optimization of programming should include identification of aberrant electrodes that produce poor sound quality or do not produce growth in loudness with increased current levels. Deactivation of these electrodes may be considered.	Bierer and Litvak (2016), Vickers et al (2016)
5)a.	ECAP and ESRT thresholds should be obtained across the electrode array at an early visit to establish a baseline of auditory function.	Gordon et al (2004b), Han et al (2005), Hodges et al (1997), Lorens et al (2004)
6)a.	Validation measures should be consistently implemented through follow-up appointments. At least one validation assessment should be included in each follow-up appointment.	Uhler and Gifford (2014), Vaerenberg et al (2014)
6)b.	Assessment of audibility through the cochlear implant and speech perception performance should be evaluated at multiple appointments during the first year of device use.	Shapiro and Bradham (2012), Uhler and Gifford (2014)
6)b.i.	For adults, evaluation of audibility and speech perception performance after the first year of device use should be evaluated at least annually or sooner if concerns of a decline in performance arise.	Vaerenberg et al (2014)
6)b.ii.	For children, evaluation of audibility and auditory, speech, and language development should be conducted routinely throughout development. More frequent monitoring of progress is warranted in those children who are in the period of developing language and auditory skills.	Bradham et al (2009), Shapiro and Bradham (2012), Uhler and Gifford (2014)
7)a.	Informational and adjustment counseling should be provided to support consistent device use, implementation of intervention strategies, and psychosocial well-being.	Shapiro and Bradham (2012), Vaerenberg et al (2014), Zaidman-Zait (2007)
8)a.	Refer the recipient for medical care with the cochlear implant surgeon if concerns arise.	Bradham et al (2009), Shapiro and Bradham (2012)
9)a.	For children, facilitate access and utilization of early intervention and educational support in compliance with local, state, and federal regulations.	Jeddi et al (2014), Shapiro and Bradham (2012)
10)a.	Discuss listening environments the user experiences and the utilization of hearing assistive technology (HAT). Support and optimization for the HAT should be included if the cochlear implant user already implements this technology.	Wolfe et al (2013), Wolfe et al (2015a), Wolfe and Schafer (2010)
11)a.	Discuss support resources and peer support groups (e.g., parent-to-parent groups for children who use cochlear implants and adult groups for adult recipients) should be included as part of routine follow-up care.	Ainbinder et al (1998), Zaidman-Zait (2007)

Care Beyond Device Programming

To realize maximum benefit from the device, cochlear implant recipients require consistent follow-up and intervention beyond cochlear implant programming. Utilization of hearing assistive technology (HAT) in addition to the cochlear implant device may be required in challenging listening environments. This section will outline the recommendations outside of device programming that should be considered to maximize individual outcomes for cochlear implant recipients.

Care Beyond Device Programming

Rec.	Evidence	Source
1)a.	All individuals who use a cochlear implant should be considered as a potential candidate for hearing assistive technology, particularly those who experience complex listening environments and school-aged children.	Schafer et al (2011), Wolfe et al (2015b)
2)a.i.	Intervention for adults may focus on auditory training. The specific interventional needs may vary based on factors known to affect outcomes.	Henshaw and Ferguson (2013), Sweetow and Palmer (2005), Tang et al (2017)
2)a.ii.	For children, intervention should focus on the holistic developmental process with the goal of auditory access and meaningful integration of sound.	Ching (2015), Entwisle et al (2016), Geers and Hayes (2010), Geers and Sedey (2010), Kaipa and Danser (2016)
2)a.ii.1.	Engaging family members in therapy and coordinating efforts among therapists and educators is believed to result in the best outcomes for children and families.	Ambrose et al (2015), DesJardin and Eisenberg (2007), Niparko et al (2010)
2)a.ii.2.	Parents should be provided with information about the range of communication options for children who are D/HH, from highly auditory, such as auditory-verbal, to highly visual, such as American Sign Language.	Standard clinical practice
2)a.ii.3.	The likelihood of a child gaining high benefit in the areas of speech perception, speech production, and spoken language increases when more emphasis is placed on listening and spoken language in the child's home and educational setting.	Ching et al (2018), Ching et al (2013), Dettman et al (2013), Fitzpatrick et al (2016), Geers (2006), Geers et al (2003), Geers et al (2017), Geers et al (2003), Kaipa and Danser (2016), Percy-Smith et al (2018), Tobey et al (2010), Tobey et al (2004)
2)a.ii.4.	High performance in children who use a cochlear implant has been linked to full-time use of the cochlear implant in home and school environments.	Easwar et al (2016), Marnane and Ching (2015)
2)a.ii.5.	Individuals who use cochlear implants can experience success in using multiple languages.	Bunta and Douglas (2013), Bunta et al (2016), Forli et al (2018), McConkey Robbins et al (2004), Thomas et al (2008)
3)a.	The amount and quality of language used by parents/caregivers of children who use cochlear implants have a strong influence on these children's linguistic development.	DesJardin and Eisenberg (2007), Moeller (2000), Niparko et al (2010), Quittner et al (2012), Tobey et al (2010)
4)a.	Materials targeting music perception and appreciation should be implemented with individuals who wish to improve music perception abilities with their cochlear implant.	Gfeller (2016), Riley et al (2018)
5)a.	The progress of individuals with special needs should be measured by the criteria that are unique to them and that reflect the goals of the family.	Hayward et al (2013), Holt and Kirk (2005), Wiley et al (2005)
6)a.	Considerations for activities of daily life and safety should be made for all individuals who use a cochlear implant. These other needs may include vocational considerations, social support, telephone use, vibrotactile alarms, and alerting devices.	Buck and Thomas (2009), Capella (2013), Thorslund et al (2013)
7)a.	Bilateral stimulation should be considered for all individuals who use a cochlear implant, if not otherwise contraindicated.	Cullington and Zeng (2011), De Raeve et al (2015), Dhondt et al (2018), Farinetti et al (2015), Gifford et al (2015), Illg et al (2014), Lammers et al (2014), Olson and Shinn (2008), Sarant et al (2014), Schafer et al (2011)

Formatting

In an attempt to produce a cohesive document, the format used in the guideline document is similar to the format used by other best practice guideline documents published and endorsed by the Academy. Formatting consists of an initial introductory statement, body of recommendations and evidence, summary tables of the aforementioned evidence, and full citations of references used in each respective section. The summary tables of each evidence include an abbreviated statement of the evidence, supporting sources, and the level, grade, and ratings of each of the sources.

The content of the guidelines was designed to recommend evidence-based practices through review of scientific evidence published in both peer-reviewed and nonpeer-reviewed journals. However, wherever gaps were identified in the research, indirect and consensus practices were implemented. Other recommendations were considered as acoustic or physical facts, where committee members did not feel an empirical evidence base was necessary, and, therefore, should not be expected. In cases where the recommendation was based on a physical or acoustic fact (a first principle), "acoustic fact" or "physical fact" is listed under "Source" in the evidence tables. Similar to other best practice guideline documents published and endorsed by the Academy, an evidence rating matrix was implemented to provide readers with access to the quality of the evidence available. This allows clinicians to consider the strength of the evidence as it applies to their own clinical decisions for each individual recipient of a cochlear implant.

Timeline of the Approval Process

An initial draft of the guidelines was made available to the public through the Academy website from March 18, 2019, through April 29, 2019. Members of the 2017 task force presented the framework for the guidelines, paired with an open forum of discussion and questions, at the annual Academy meeting in Columbus, Ohio, in 2019. Feedback provided to the committee was implemented and addressed. An updated draft was sent to the Academy board of directors and was approved at the July 2019 Meeting. The board-approved document is now available for public access at audiology.org.

Limitations and Future Directions of the Guidelines Document

The practice guidelines for cochlear implant document serve as the first of its kind, offering audiologists access to streamlined, evidence-based information to help make appropriate clinical decisions for each of their individual patients. It should be noted, however, that cochlear implant research faces challenges in providing standards that can be applied across all cochlear implant recipients. Because of the increasing number of known factors impacting outcomes and success for a cochlear implant, there are limited opportunities to conduct controlled research in the field of cochlear implants. Furthermore, the controlled research available on cochlear implants is continually limited by factors such as small sample sizes, a wide range of device options, and complex case histories. Therefore, it is difficult to apply evidence across all or even a larger subset of recipients of a cochlear implant. It is imperative that the practicing audiologist consider the evidence alongside the needs of each individual they treat to provide best clinical care.

Although new evidence continues to emerge toward new approaches to cochlear implant care, it was not considered within the scope of this current document to explore those experimental practices. Therefore, the authors and task force members acknowledge the limitations of the current document in its use for clinicians. Future versions, or subversions, of the cochlear implant best practice guidelines will be imperative as more supporting evidence becomes available. Furthermore, the task force acknowledges limitations in combining both adult and pediatric recommendations into a single guideline document. Special consideration was made throughout various sections of the guideline document to acknowledge differences in the recommended approach to caring for adult versus pediatric populations. The task force recommends that future iterations of the document consider providing separate sections or completely separate documents for adult and pediatric cochlear implant recipients to provide more in-depth considerations for these differing groups.

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