

Cochlear Implant

Effective: December 1, 2023

Next Review: March 2024

Last Review: July 2023

IMPORTANT REMINDER

Medical Policies are developed to provide guidance for members and providers regarding coverage in accordance with contract terms. Benefit determinations are based in all cases on the applicable contract language. To the extent there may be any conflict between the Medical Policy and contract language, the contract language takes precedence.

PLEASE NOTE: Contracts exclude from coverage, among other things, services or procedures that are considered investigational or cosmetic. Providers may bill members for services or procedures that are considered investigational or cosmetic. Providers are encouraged to inform members before rendering such services that the members are likely to be financially responsible for the cost of these services.

DESCRIPTION

A cochlear implant is a device for the treatment of severe-to-profound hearing loss in individuals who only receive limited benefit from amplification with hearing aids. A cochlear implant provides direct electrical stimulation to the auditory nerve, bypassing the usual transducer cells that are absent or nonfunctional in deaf cochlea.

MEDICAL POLICY CRITERIA

Notes:

- This policy does not apply to surgically anchored bone-conduction hearing aids or externally worn air-conduction hearing aids. Cochlear implants are not hearing aids. While hearing aids function by amplifying sound, cochlear implants replace the functions of an absent or nonfunctioning cochlea.
- This policy does not address the use of the Nucleus® 24 Auditory Brain Stem Implant, which is designed to restore hearing in patients with neurofibromatosis who are deaf secondary to removal of bilateral acoustic neuromas.
- Hybrid cochlear implant/hearing aid systems are devices that include a hearing aid integrated into the external sound processor of the cochlear implant. If hearing aid

components of such systems are billed separately, there may be specific member benefit language addressing coverage of hearing aids that would be applicable. Contract language takes precedence over medical policy.

- Repeat hearing tests or trials of hearing aids are not necessary for patients who have previously met Criteria I. and II. as it is unlikely that natural hearing or the benefit from hearing aids will improve significantly over time.

I. **For individuals with bilateral hearing loss, implantation of cochlear implants (unilateral or bilateral), other than cochlear implant/hearing aid hybrid devices, and associated aural rehabilitation may be considered **medically necessary** when all of the following criteria (A. – D.) are met:**

A. Meets one of the following age requirements:

1. Age 9 months or older for the Nucleus 24 cochlear implant system (with any of the Cochlear® sound processors); or
2. Age 12 months or older.

B. Meets one or more of the following:

1. Patients diagnosed with enlarged vestibular aqueduct (EVA) (greater than 1mm at the midpoint), as evidenced by MRI or CT imaging; or
2. Patients with both of the following (a. and b.):

a. Patients meeting criterion (i. or ii.):

- i. Bilateral severe to profound pre- or postlingual (sensorineural) hearing loss, defined as a pure-tone average of 70 decibels (dB) hearing threshold or greater at 500 Hz (hertz), 1000 Hz and 2000 Hz; or
- ii. Severe to profound pre- or postlingual (sensorineural) hearing loss, defined as a pure-tone average of 70 dB hearing threshold or greater at 500 Hz (hertz), 1000 Hz and 2000 Hz in one ear with documented progressive hearing loss (i.e., documentation of multiple audiograms demonstrating progressive hearing loss with expectation of continued progressive hearing loss) in the contralateral ear; and

b. Limited or no benefit from hearing aids (defined below) unless hearing aids are unreasonable.

i. **Adults:** Scores less than or equal to 50 percent correct on tape recorded sets of open-set sentence recognition in the ear to be implanted.

ii. **Children:** Failure to develop basic auditory skills, and in older children, less than or equal to 30 percent correct on open-set tests.

C. Implanted device is FDA approved PMA or 510(k) only.

D. Patients do not have any of the following contraindications:

1. Deafness due to lesions of the acoustic nerve (eighth cranial nerve), central auditory pathways, or brain stem in the implanted ear.

2. Active or chronic infections of the external or middle ear and mastoid cavity in the implanted ear, including but not limited to otitis media.
3. Tympanic membrane perforation.
4. Radiographic evidence of absent cochlear development in the implanted ear.
5. Inability or lack of willingness to participate in post-implantation aural rehabilitation.

II. **For individuals with bilateral hearing loss, unilateral implantation of hybrid cochlear implant/hearing aid systems** that include the hearing aid integrated into the external sound processor of the cochlear implant may be considered **medically necessary** when all of the following criteria are met (A. – F.):

- A. Age 18 years or older.
- B. Bilateral severe to profound pre- or postlingual (sensorineural) hearing loss, defined as a pure-tone average of 70 decibels (dB) hearing threshold or greater at 500 Hz (hertz), 1000 Hz and 2000 Hz.
- C. Limited or no benefit from hearing aids unless hearing aids are unreasonable, defined as scores less than 50 percent correct on tape recorded sets of open-set sentence recognition in the ear selected for implantation.
- D. Meets all of the following (1. and 2.):
 1. All of the following in the ear selected for implantation (a. – c.):
 - a. Low frequency hearing thresholds no poorer than 60 dB hearing level up to and including 500 Hz (averaged over 125, 250, and 500 Hz; i.e., threshold average of 125, 250, and 500 Hz less than or equal to 60 dB hearing level); and
 - b. Severe to profound mid-to-high frequency hearing loss (threshold average of 2000, 3000, and 4000 Hz greater than or equal to 75 dB hearing level); and
 - c. Aided consonant-nucleus-consonant word recognition score from 10 percent to 60 percent in the preoperative aided condition.
 2. All of the following for the contralateral ear (a and b):
 - a. Moderately severe to profound mid-to-high frequency hearing loss (threshold average of 2000, 3000, and 4000 Hz greater than or equal to 60 dB hearing level); and
 - b. Aided consonant-nucleus-consonant word recognition score equal to or better than that of the ear selected for implantation but not more than 80 percent correct.
- E. Implanted device is FDA approved PMA or 510(k) only.
- F. Does not have any of the following contraindications:
 1. Deafness due to lesions of the acoustic nerve (eighth cranial nerve), central auditory pathways, or brain stem in the implanted ear

2. Active or chronic infections of the external or middle ear and mastoid cavity in the implanted ear, including but not limited to otitis media
3. Tympanic membrane perforation
4. Radiographic evidence of absent cochlear development in the implanted ear
5. Inability or lack of willingness to participate in post-implantation aural rehabilitation
6. A duration of severe to profound hearing loss of 30 years or greater.

III. **For individuals with unilateral hearing loss (single sided deafness), unilateral implantation of cochlear implant, other than cochlear implant/hearing aid *hybrid* devices, and associated rehabilitation may be considered **medically necessary** when all of the following criteria (A. - F.) are met:**

- A. Five years of age or older.
- B. Profound sensorineural hearing loss in one ear (defined as having a pure-tone average of 90dB hearing loss or greater at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.)
- C. One of the following in the contralateral ear (1. or 2.):
 1. Normal hearing or mild sensorineural hearing loss in the contralateral ear. Normal hearing is defined as having a PTA of up to 15 dB Hearing Loss at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. (i.e., single sided deafness); or
 2. Mild to moderately severe sensorineural hearing loss in the contralateral ear, with a difference of at least 15 dB in pure tone averages (PTAs) between ears (i.e., asymmetric hearing loss).
- D. Documented limited benefit from an appropriately fitted unilateral hearing aid in the ear to be implanted.
- E. Implanted device is FDA approved - PMA or 510(k) only.
- F. Does not have any of the following contraindications:
 1. Deafness due to lesions of the acoustic nerve (eighth cranial nerve), central auditory pathways, or brain stem in the implanted ear.
 2. Active or chronic infections of the external or middle ear and mastoid cavity in the implanted ear, including but not limited to otitis media.
 3. Tympanic membrane perforation.
 4. Radiographic evidence of absent cochlear development in the implanted ear.
 5. Inability or lack of willingness to participate in post-implantation aural rehabilitation.

IV. Implantation of cochlear implants is considered **not medically necessary** when one of Criterion I. II. or III. above is not met.

V. **Implant replacement, including replacement parts or upgrades** to existing cochlear implants and/or components, may be considered **medically necessary** when components are no longer functional, or for functional devices only in the small subset

of patients whose response to existing components is inadequate to the point of interfering with activities of daily living, which would include school and work.

- VI. **Implant replacement, including replacement parts or upgrades** to existing cochlear implants and/or components, are considered **not medically necessary** when Criterion V. is not met, including but not limited to upgrades of existing, functioning external systems to achieve aesthetic improvement, such as smaller profile components, or a switch from a body-worn external sound processor to a behind-the-ear (BTE) model.

NOTE: A summary of the supporting rationale for the policy criteria is at the end of the policy.

POLICY GUIDELINES

A Pure Tone Average (PTA) is determined by averaging the hearing threshold levels at a set of specified frequencies: for example, 500, 1000, and 2000 Hz (PTA = 500 Hz (T)+ 1000 Hz (T) + 2000Hz (T) ÷ 3).

LIST OF INFORMATION NEEDED FOR REVIEW

REQUIRED DOCUMENTATION:

It is critical that the list of information below is submitted for review to determine if the policy criteria are met. If any of these items are not submitted, it could impact our review and decision outcome.

- History and Physical/Chart Notes
- Manufacturer and Model Name of Cochlear Implant being requested
- Audiology test results

CROSS REFERENCES

1. [Transcutaneous Bone-Conduction and Bone-Anchored Hearing Aids](#), Surgery, Policy No. 121

BACKGROUND

Hearing loss is rated on a scale based on the threshold of hearing sounds, measured in decibels (dB). The generally accepted range for human hearing is 0 -120 dB (where 0 dB is no sound, 120 dB is very loud). Severe hearing loss is defined as a hearing threshold of 70-90 decibels (dB) and profound hearing loss is defined as a hearing threshold of 90 dB and above. Profound unilateral sensorineural hearing loss (UHL) or single-sided deafness (SSD), is clinically unaidable hearing defined by severe-to-profound hearing thresholds with a poor word recognition ability.

A cochlear implant provides direct electrical stimulation to the auditory nerve, bypassing the usual transducer cells that are absent or nonfunctional in deaf cochlea. The basic components of a cochlear implant include both external and internal components. The external components include a microphone, an external sound processor, and an external transmitter. The internal components are implanted surgically and include an internal receiver implanted within the temporal bone, and an electrode array that extends from the receiver into the cochlea through a surgically created opening in the round window of the middle ear.

Sounds that are picked up by the microphone are carried to the external signal processor, which transforms sound into coded signals that are then transmitted transcutaneously to the implanted internal receiver. The receiver converts the incoming signals to electrical impulses that are then conveyed to the electrode array, ultimately resulting in stimulation of the auditory nerve.

Cochlear implants may be implanted in one or both ears. Implantation in both ears can be done sequentially or simultaneously. A post-cochlear implant rehabilitation program is necessary to achieve benefit from the cochlear implant. The rehabilitation program includes development of skills in understanding running speech, recognition of consonants and vowels, and tests of speech perception ability.

REGULATORY STATUS

Note: Full FDA approval includes only Premarket Approval (PMA) and 510k approval. Devices with Investigational Device Exemption (IDE) or Humanitarian Device Exemption (HDE) are not considered fully FDA approved.

Several cochlear implants are commercially available in the United States. The FDA-labeled indications for currently marketed electrode arrays are summarized in the table below. Over the years, subsequent generations of the various components of the devices have been FDA approved, focusing on improved electrode design and speech-processing capabilities. Furthermore, smaller devices and the accumulating experience in children have resulted in broadening of the selection criteria to include children as young as 9 months.

Manufacturer and FDA approved Cochlear Implants	Indications for Adults or Children
CONVENTIONAL COCHLEAR IMPLANTS	
<p>Advanced Bionics®</p> <ul style="list-style-type: none"> • HiRes™ Ultra implant • HiResolution Bionic Ear System (HiRes 90K*) <p>Sound Processors:</p> <ul style="list-style-type: none"> • ClearVoice • HiRes Fidelity 120 • HiRes Optima <p>Predecessors:</p> <ul style="list-style-type: none"> • Clarion Multi-Strategy • HiFocus CII Bionic Ear 	<p style="text-align: center;"><u>Adults:</u></p> <ul style="list-style-type: none"> • ≥ 18 years of age • Post-lingual onset of severe to profound bilateral sensorineural hearing loss [≥70 decibels (dBs)] • Limited benefit from appropriately fitted hearing aids, defined as scoring ≤ 50% on a test of open-set Hearing in Noise Test (HINT) sentence recognition <p style="text-align: center;"><u>Children:</u></p> <ul style="list-style-type: none"> • 12 months to 17 years of age • Profound bilateral sensorineural deafness (>90dB) • Use of appropriately fitted hearing aids for at least 6 months in children 2 to 17 years of age or at least 3 months in children 12 to 23 months of age. • Lack of benefit in children <4 years of age is defined as a failure to reach developmentally-appropriate auditory milestones (e.g., spontaneous response to name in quiet or to environmental sounds) measured using the Infant-Toddler Meaningful Auditory Integration Scale or Meaningful Auditory Integration Scale or < 20% correct on a simple open-set word recognition test (Multisyllabic Lexical Neighborhood Test) administered using monitored live voice [70 dB SPL (sound pressure level)]

Manufacturer and FDA approved Cochlear Implants	Indications for Adults or Children
	<ul style="list-style-type: none"> Lack of hearing aid benefit in children >4 years of age is defined as scoring < 12% on a difficult open-set word recognition test (Phonetically Balanced-Kindergarten Test) or < 30% on an open-set sentence test (HINT for Children) administered using recorded materials in the soundfield (70 dB SPL)
<p>Cochlear®</p> <ul style="list-style-type: none"> Nucleus CI600 series Nucleus CI500 series Nucleus CI24RE series Nucleus 24 series <p>Sound Processors:</p> <ul style="list-style-type: none"> Kanso® 2 Kanso® Nucleus® 8 Nucleus® 7 Nucleus® 6 Nucleus® 5* Nucleus Freedom <p>Predecessors:</p> <ul style="list-style-type: none"> Nucleus 22, 24 	<p style="text-align: center;"><u>Adults:</u></p> <ul style="list-style-type: none"> ≥ 18 years old Pre- or post-lingual onset of moderate to profound bilateral sensorineural hearing loss ≤50% sentence recognition in the ear to be implanted ≤60% sentence recognition in the opposite ear or binaurally Adults with Severe to profound unilateral SNHL (SSD or AHL) <ul style="list-style-type: none"> PTA at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of > 80 dB HL Normal or near normal hearing in the contralateral ear defined as PTA at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of ≤ 30 dB HL Limited benefit from an appropriately fitted unilateral hearing device <p style="text-align: center;"><u>Children 9 months to 24 months:</u></p> <ul style="list-style-type: none"> Profound sensorineural hearing loss bilaterally Limited benefit from appropriate binaural hearing aids Lack of progress in the development of auditory skills <p style="text-align: center;"><u>Children 25 months to 17 years 11 months:</u></p> <ul style="list-style-type: none"> Severe to profound bilateral sensorineural hearing loss Multi-syllabic Lexical Neighborhood Test (MLNT) scores of ≤30% in best-aided condition in children 25 months to 4 years 11 months Lexical Neighborhood Test (LNT) scores of ≤30% in best-aided condition in children 5 years to 17 years and 11 months Lack of progress in the development of auditory skills Children 5 y to 18 y of age with severe to profound unilateral SNHL (SSD or AHL) <ul style="list-style-type: none"> PTA at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of > 80 dB HL Normal or near normal hearing in the contralateral ear defined as PTA at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of ≤ 30 dB HL Limited benefit from an appropriately fitted unilateral hearing device
<p>Med EI®</p> <ul style="list-style-type: none"> Maestro system Synchrony Implant 	<p style="text-align: center;"><u>Bilateral Hearing Loss</u></p> <p style="text-align: center;"><u>Adults:</u></p> <ul style="list-style-type: none"> ≥ 18 years old

Manufacturer and FDA approved Cochlear Implants	Indications for Adults or Children
<ul style="list-style-type: none"> • Synchrony 2 Implant • Concerto Implant <p>Sound Processors:</p> <ul style="list-style-type: none"> • Sonnet • Sonnet 2 • Concerto implant • Opus • Opus 2 • Rondo 2 <p>Predecessors:</p> <ul style="list-style-type: none"> • Combi 40+ • Sonata • Pulsar 	<ul style="list-style-type: none"> • Severe to profound bilateral sensorineural hearing loss (≥ 70dB) • $\leq 40\%$ correct Hearing in Noise test (HINT) sentences with best-sided listening condition <p style="text-align: center;"><u>Children:</u></p> <ul style="list-style-type: none"> • 12 months to 18 years with profound sensorineural hearing loss (≥ 90dB) • In younger children, little or no benefit is defined by lack of progress in the development of simple auditory skills with hearing aids over a 3-6 month period • In older children, lack of aided benefit is defined as $< 20\%$ correct on the MLNT or LNT depending upon the child's cognitive ability and linguistic skills • A 3-6 month trial with hearing aids is required if not previously experienced <p style="text-align: center;"><u>Single-Sided Deafness and Asymmetric Hearing Loss</u></p> <ul style="list-style-type: none"> • ≥ 5 years old • Single-sided deafness (SSD) or asymmetric hearing loss (AHL), where: <ul style="list-style-type: none"> ○ SSD is defined as profound sensorineural hearing loss in one ear and normal hearing or mild sensorineural hearing loss in the other ear. ○ AHL is defined as a profound sensorineural hearing loss in one ear and mild to moderately severe sensorineural hearing loss in the other ear, with a difference of at least 15 dB in pure tone averages (PTAs) between ears. • Limited benefit from an appropriately fitted unilateral hearing aid in the ear to be implanted. • For ages 18 years-old and above, limited benefit from unilateral amplification is defined by test scores of 5% correct or less on monosyllabic consonant-nucleus-consonant (CNC) words in quiet when tested in the ear to be implanted alone. • For ages between 5 and 18 years-old, insufficient functional access to sound in the ear to be implanted must be determined by aided speech perception test scores of 5% or less on developmentally appropriate monosyllabic word lists when tested in the ear to be implanted alone • At least 1 month experience wearing a Contra Lateral Routing of Signal (CROS) hearing aid or other relevant device and not show any subjective benefit
<p>Oticon Medical</p> <p>Neuro Cochlear Implant System (Neuro 2 sound processor and Neuro Zti implant)</p>	<p style="text-align: center;"><u>Adults:</u></p> <ul style="list-style-type: none"> • Severe-to-profound bilateral SNHL (≥ 70 dB at 500, 1000, and 2000 Hz) • Limited benefit from appropriately fit hearing aids, defined as scoring $\leq 50\%$ correct HINT sentences in quiet or noise with best-sided listening condition
HYBRID COCHLEAR IMPLANTS	

Manufacturer and FDA approved Cochlear Implants	Indications for Adults or Children
Cochlear® <ul style="list-style-type: none"> Nucleus® Hybrid™ L24 Cochlear Implant (Nucleus 6) 	<u>Adults:</u> <ul style="list-style-type: none"> ≥ 18 years old Residual low-frequency hearing sensitivity Severe to profound high-frequency sensorineural hearing loss Limited benefit from appropriately fit bilateral hearing aids
Med El® <ul style="list-style-type: none"> Med EL EAS™ 	<u>Adults:</u> <ul style="list-style-type: none"> ≥ 18 years old Residual low-frequency hearing sensitivity Severe to profound high-frequency sensorineural hearing loss Candidates should go through a suitable hearing aid trial, unless already appropriately fit with hearing aids
RECENTLY FDA-APPROVED DEVICES	
<ul style="list-style-type: none"> New devices that come onto the market are added to the policy at policy updates. In the interim, new devices may be approved for coverage for FDA-approved indications when applicable criteria are met.** 	

*Note: Cochlear, Ltd. voluntarily recalled the Nucleus CI500 range in September 2011 for device malfunction in the CI512 implant. The external Nucleus 5 sound processor is not a part of the recall. Advanced Bionics HiRes90K was voluntarily recalled in November 2010 and given FDA-approval for re-entry to market the device in September 2011.

** FDA-approved indications can be found by searching by device name in the FDA [510\(k\) Premarket Notification Database](#) or the [De Novo Database](#) and viewing the Summary.

While cochlear implants have typically been used mono laterally, in recent years, interest in bilateral cochlear implantation has arisen. The proposed benefits of bilateral cochlear implants are to improve understanding of speech in noise and localization of sounds. Improvements in speech intelligibility may occur with bilateral cochlear implants through binaural summation; i.e., signal processing of sound input from two sides may provide a better representation of sound and allow one to separate out noise from speech. Speech intelligibility and localization of sound or spatial hearing may also be improved with head shadow and squelch effects, i.e., the ear that is closest to the noise will be received at a different frequency and with different intensity, allowing one to sort out noise and identify the direction of sound. Bilateral cochlear implantation may be performed independently with separate implants and speech processors in each ear or with a single processor. However, no single processor for bilateral cochlear implantation has been FDA approved for use in the United States. In addition, single processors do not provide binaural benefit and may impair localization and increase the signal to noise ratio received by the cochlear implant.

In March 2014, FDA approved the Nucleus® Hybrid™ L24 Cochlear Implant System (Cochlear Corporation) through the premarket approval process.^[1] This system is a hybrid cochlear implant and hearing aid, with the hearing aid integrated into the external sound processor of the cochlear implant. It is indicated for unilateral use in patients aged 18 years and older who have residual low-frequency hearing sensitivity and severe to profound high-frequency sensorineural hearing loss, and who obtain limited benefit from appropriately fit bilateral hearing aid. The electrode array inserted into the cochlea is shorter than conventional cochlear implants. According to the FDA’s premarket approval notification, labeled indications for the device include:

- Preoperative hearing in the range from normal to moderate hearing loss (HL) in the low frequencies (thresholds no poorer than 60 dB HL up to and including 500 Hz).
- Preoperative hearing with severe to profound mid- to high-frequency hearing loss (threshold average of 2000, 3000, and 4000 Hz ≥ 75 dB HL) in the ear to be implanted.
- Preoperative hearing with moderately severe to profound mid- to high-frequency hearing loss (threshold average of 2000, 3000, and 4000 Hz ≥ 60 dB HL) in the contralateral ear.
- Consonant-Nucleus-Consonant (CNC) word recognition score between 10% to 60% (inclusively) in the ear to be implanted in the preoperative aided condition and in the contralateral ear equal to or better than that of the ear to be implanted but not more than 80% correct.

In January 2022, the FDA approved to expand the indication for the Nucleus 24 Cochlear Implant System to individuals aged 5 years and older with single-sided deafness (SSD) or asymmetrical hearing loss (AHL).^[2]

According to the FDA's summary of safety and effectiveness data, approval was based on unpublished data in 42 adults from a feasibility study (n=10) and real-world data from two cochlear implantation centers (n=32). Study interpretation is limited by small sample size in adult subjects only, unclear rationale for the efficacy threshold, and missing data. The FDA has required Cochlear Americas to conduct a postmarketing study to continue to assess the safety and efficacy of the implant in a new enrollment cohort of adults and children. (P970051/S205).

In September 2016, FDA approved the Med EL EAS™ (Electric Acoustic Stimulation) Hearing Implant System (Med EL Corp.).^[3] This system is a hybrid cochlear implant and hearing aid, with the hearing aid integrated into the external sound processor of the cochlear implant. It is the combination of the SYNCHRONY cochlear implant and the SONNET EAS audio processor. According to the FDA's premarket approval notification:^[4]

The MED-EL EAS System is indicated for partially deaf individuals aged 18 years and older who have residual hearing sensitivity in the low frequencies sloping to a severe/profound sensorineural hearing loss in the mid to high frequencies, and who obtain minimal benefit from conventional acoustic amplification. Typical preoperative hearing of candidates ranges from normal hearing to moderate sensorineural hearing loss in the low frequencies (thresholds no poorer than 65 dB HL up to and including 500 Hz) with severe to profound mid- to high-frequency hearing loss (no better than 70 dB HL at 2000 Hz and above) in the ear to be implanted. For the non-implanted ear, thresholds may be worse than the criteria for the implanted ear, but may not be better. The CNC word recognition score in quiet in the best-aided condition will be 60% or less, in the ear to be implanted and in the contralateral ear. Prospective candidates should go through a suitable hearing aid trial, unless already appropriately fit with hearing aids.

In July 2019, the FDA expanded indications for the MED-EL Cochlear Implant System to include SSD and AHL.^[5]

The indications for use are as follows: The MED-EL Cochlear Implant System is indicated for evoking auditory sensations via electrical stimulation of the auditory pathways for individuals ages 5 years and above with single-sided deafness (SSD) or asymmetric hearing loss (AHL), where: SSD is defined as profound sensorineural hearing loss in one ear and normal hearing or mild sensorineural hearing loss in the

other ear. AHL is defined as a profound sensorineural hearing loss in one ear and mild to moderately severe sensorineural hearing loss in the other ear, with a difference of at least 15 dB in pure tone averages (PTAs) between ears. Profound hearing loss is defined as having a PTA of 90 dB HL or greater at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Normal hearing is defined as having a PTA of up to 15 dB HL at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Mild hearing loss is defined as having a PTA of up to 30 dB HL at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Mild to moderately severe hearing loss is defined as having a PTA ranging from 31 to up to 55 dB HL at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Individuals with SSD or AHL must obtain limited benefit from an appropriately fitted unilateral hearing aid in the ear to be implanted. For individuals ages 18 years-old and above, limited benefit from unilateral amplification is defined by test scores of five (5) percent correct or less on monosyllabic consonant-nucleus-consonant (CNC) words in quiet when tested in the ear to be implanted alone. For individuals between 5 and 18 years-old, insufficient functional access to sound in the ear to be implanted.

EVIDENCE SUMMARY

Cochlear implants (CI) are recognized effective treatment of sensorineural deafness in select patient, as noted in a 1995 National Institutes of Health Consensus Development conference, which offered the following conclusions:^[6]

- Cochlear implantation has a profound impact on hearing and speech reception in postlingually deafened adults with positive impacts on psychological and social functioning.
- The results are more variable in children. Benefits are not realized immediately but rather are manifested over time, with some children continuing to show improvement over several years.
- Prelingually deafened adults may also benefit, although to a lesser extent than postlingually deafened adults. These individuals achieve minimal improvement in speech recognition skills. However, other basic benefits, such as improved sound awareness, may meet safety needs.
- Training and educational intervention are fundamental for optimal post implant benefit.
- Cochlear implants in children under two years old are complicated by the inability to perform detailed assessment of hearing and functional communication. However, a younger age of implantation may limit the negative consequences of auditory deprivation and may allow more efficient acquisition of speech and language. Some children with post-meningitis hearing loss have been implanted under the age of two years due to the risk of new bone formation associated with meningitis, which may preclude a cochlear implant at a later date.

ENLARGED VESTIBULAR AQUEDUCTS (EVA)

Enlarged vestibular aqueduct (also known as enlarged vestibular aqueduct syndrome (EVAS), large vestibular aqueduct, large vestibular aqueduct syndrome (LVAS), or dilated vestibular aqueduct) is a condition which is associated with childhood hearing loss. According to the NIH National Institute on Deafness and other Communication Disorders (NIDCD):^[7] most children with enlarged vestibular aqueducts (EVA) will develop some amount of hearing loss, and approximately 5 to 15% of children with sensorineural hearing loss (hearing loss caused by damage to sensory cells inside the cochlea) have EVA.

Systematic Reviews

Alahmadi (2022) published a systematic review (SR) evaluating the surgical and clinical outcomes of cochlear implant among patients with EVA.^[8] Of the 4035 subjects (34 studies) included, 853 (21.14%) underwent cochlear implantation. Unilateral implantation was performed in 258 cases while bilateral in 119 subjects. Postoperative complications included CSF/perilymph gusher (n = 112), CSF oozing (n = 18), and partial electrode insertion (n = 6). Closing the cochleostomy with temporalis fascia, muscle, connective tissue, or fibrin glue was the most frequently reported approach to manage CSF/perilymph gusher (n = 67, 56.7%) while packing was performed in six patients. The authors conclude that patients with EVA demonstrated audiometric and speech performance improvement after CI. However, many patients had intra- or postoperative complications.

Hansen (2022) published a SR to evaluate the age at implantation, improvement in hearing and speech perception outcomes, as well as surgical complications in pediatric cochlear implant recipients with Pendred Syndrome (PS) or non-syndromic enlarged vestibular aqueduct (NSEVA). A total of 55 studies were included in the analysis. The authors reported that the four-frequency pure-tone audiogram average improved by 60 to 78 dB HL due to cochlear implantation (in 46 studies with audiogram results). Auditory performance and speech intelligibility scores increased by 44%. The overall average implantation age was 60 months. Perilymph gusher/oozing was the most common surgical incident reported, occurring in 187 of 1572 implantations. The authors conclude that in children with PS/NSEVA, cochlear implantation improves pure-tone average by 60 to 78 dB HL and capacity of auditory performance/speech intelligibility by 44%. The implantation age for these children has decreased during the last two decades but is still somewhat higher than reported for unselected pediatric cochlear implantation.

Pan (2022) reported a SR and meta-analysis of the safety and effectiveness of cochlear implantation for patients with large vestibular aqueduct deformity.^[9] A total of five randomized controlled trials met inclusion criteria. There was low to high risk of bias for blinding of participants and personnel and low or unclear risk of bias for the other evaluated biases. Meta-analysis evaluated postoperative hearing ability and speech intelligibility rate between EVA patients and those with normal inner ear structure. No significant differences between groups were identified.

In 2014, Xu conducted a SR in Chinese to assess the efficacy and safety of cochlear implantation in deaf patients with inner ear malformations compared to deaf patients with normal inner ear structure, including 11 RTCs (n=655 patients).^[10] In terms of postoperative complications, electrode impedance, behavior T-level, hearing abilities and speech discrimination; patients with mixed inner ear malformations, Mondini syndrome or EVA were not significantly different than controls. However, the reviewers concluded that additional larger controlled studies with longer follow-up may help to evaluate the efficacy of cochlear implantation for deaf patients with inner ear malformation more reliably.

Pakdaman (2012) conducted a SR to determine if abnormal cochleovestibular anatomy influences surgical and audiologic outcomes following cochlear implant (CI) surgery in children, including 22 studies.^[11] Out of the 311 children included, 89 (29%) were diagnosed with EVA, considered to be a mild/moderate anomaly. Outcomes of CI surgery were analyzed based on the severity of the ear malformation (mild/moderate anomaly versus severe), and subgroup analyses were not performed based on the different malformations observed. The reviewers

reported that severe inner ear dysplasia was associated with increased surgical difficulty and lower speech perception.

Nonrandomized Studies

There have been a number of case series and retrospective analyses published on the efficacy of cochlear implants in patients with EVA, all generally reporting an improvement of outcomes including various clinical scores for hearing improvement and scores measuring quality of life. These studies range in size from three to 47 cases.^[12-22] Some of these studies have focused on pediatric patients, while others have included mixed patient populations and have not analyzed pediatric patients from adults in terms of outcomes. Overall, these studies report that outcomes in EVA patients are comparable to cochlear implant patients with no malformations, including similar risk of cerebrospinal fluid (CSF) gusher during cochlear implantation.

There is research indicating that the age of cochlear implantation for patients with EVA affects health outcomes. In 2013, Ko conducted a study (1) to assess health outcomes of Mandarin-speaking patients with EVA after cochlear implantation (CI); (2) to compare their performance with a group of CI users without EVA; (3) to understand the effects of age at implantation and duration of implant use on the CI outcomes.^[23] Forty-two patients with EVA participating in this study were divided into two groups: the early group received CI before five years of age and the late group after five years of age. The patients with EVA with more than five years of implant use (18 cases) achieved a mean score higher than 80% on the most recent speech perception tests and reached the highest level on the CAP/SIR scales. The early group developed speech perception and intelligibility steadily over time, while the late group had a rapid improvement during the first year after implantation. The two groups, regardless of their age at implantation, reached a similar performance level. These patients do not necessarily need to wait until their hearing thresholds are higher than 90 dB HL or PB word score lower than 40% to receive CI. Similar results have been reported in small pediatric case series, indicating that if patients receive cochlear implants prior to becoming severely to profoundly deaf, that residual hearing is preserved.^[12, 24]

In contrast to studies reporting favorable outcomes, one small retrospective study performed by Bichy in 2002 that reported better hearing outcomes in patients with EVA using hearing aid than those who had undergone cochlear implantation.^[25] The analysis in this study included 16 children and adults with EVA that had undergone cochlear implantation and 10 children and adults undergoing treatment of progressive or fluctuant sensorineural hearing loss with the use of a hearing aid alone. Although the hearing aid group had a better mean pure-tone average (70.8 dB; SD 24.4) versus (107.0 dB; SD 21.7) for the cochlear implant group, the use of health utility indexes determined that greater net health benefit (including quality of life) was derived from cochlear implantation over hearing aids.

INFANTS UNDER AGE 12 MONTHS

The literature review focused on studies comparing the impact on hearing, speech development and recognition, and complication rates of implantation in infants younger than 12 months with those of older age groups. This includes the question of whether any early benefits that may occur in these very young patients later converge with those in older patients.

Systematic Reviews

Sbeih (2022) reported a SR that assessed the safety of cochlear implantation in children 12 months and younger.^[26] A total of 18 studies met inclusion criteria. Major and minor complications were reported in 3.1% and 2.4% of patients, respectively. The authors noted that this is similar to rates of complications in older cohorts.

Two older SRs were identified that addressed CI in children under 12 months of age. The reviews, summarized below, reported few studies of CI in this age group compared with CI in children over one year of age. Both systematic reviews ranked the available studies as poor to fair due to heterogeneity in study participants and study designs, and high risk for potential bias. In addition, differences in outcomes between the age groups did not reach statistical significance.

In 2011 Forli reported similar findings in seven studies comparing CI implanted prior to one year of age with implantations performed after one year of age.^[27] The studies precluded meta-analysis due to heterogeneity of age ranges analyzed and outcomes evaluated. While studies suggested improvements in hearing and communicative outcomes in children receiving implants prior to one year of age, between-group differences did not reach statistical significance. In addition, it is not certain whether any improvements were related to duration of cochlear implant usage rather than age of implantation. Nor is it clear whether any advantages of early implantation are retained over time.

In 2010, Vlastarakos conducted a SR of studies on bilateral cochlear implants in a total of 125 children implanted before one year of age.^[28] The authors noted that follow-up times ranged from a median duration of 6 to 12 months and, while results seemed to indicate accelerated rates of improvement in implanted infants, the evidence available was limited and of lower quality. Additionally, the lack of reliable outcome measures for infants demonstrated the need for further research before cochlear implantation prior to one year of age becomes widespread.

Nonrandomized Studies

In March 2020, the FDA approved an expansion of the indications for Cochlear Americas' Nucleus 24 cochlear implant system for infants aged 9 to 12 months of age with bilateral profound sensorineural deafness who demonstrate limited benefit from appropriate binaural hearing aids. Previously, this device was approved for ages 12 months and older. According to the FDA's summary of safety and effectiveness data, approval was based on supporting evidence from a comprehensive literature review and a clinical feasibility study. The clinical feasibility study was a retrospective clinical analysis of 84 subjects implanted with cochlear implants between the ages of 9 and 12 months. Descriptive statistics were reported for time under anesthesia (unilateral: 2hrs 34min, bilateral: 4hrs 15min), estimated blood loss (unilateral: 10.75 cc, bilateral: 19.88 cc), time in recovery (unilateral: 2hr 18min, bilateral: 1hr 59min), and adverse events (Percent of subjects: 2.4% cerebral spinal fluid leak; 2.4% facial weakness; 2.4% infection; 7.1% minor post-op complication; 3.6% minor skin irritation; 3.6% otitis media; 2.4% seroma; 7.1% temperature regulation during procedure).

The supporting literature review identified 49 articles including 750 total (not necessarily unique) patients implanted with cochlear implants prior to 12 months of age. Safety results were reported on a per-study basis with no meta-analysis. Complication rates were reported between 1.5% and 10% except for two studies. One reported a rate of 29%, and the other reported on two techniques, one of which had a rate of 20.6% and the other 61.5%. Two studies compared complications across different age ranges. One reported similar complication rates across ages and the other reported higher rates for younger ages. The

summary section states that the study findings support that the safety profile for cochlear implantation in pediatric patients who are implanted between 9 and 12 months of age is comparable to that of the currently approved population of age 12 months and older. Effectiveness results were reported on a per-study basis with no meta-analysis. No study reported worse hearing outcomes for the early-implanted group and many reported significantly better outcomes for this group.

A 2017 retrospective study by Kalejaiye assessed surgical complications, operative times, and reoperation rates in 73 patients under one year of age.^[30] They compared these patients, identified from the American College of Surgeons National Surgical Quality Improvement Program Pediatric database (2012-2013), with pediatric patients in the database above the age of one. They found that the patients under one year had higher readmission rates (6.9% vs. 2.7%) and longer mean operative times (191 minutes vs. 160 minutes), but no significant differences were noted in complication rate, postoperative length of stay, or reoperation rate.

In 2015, Guerzoni conducted a prospective study of 28 children with profound sensorineural hearing loss who were implanted early with cochlear implants (mean age at device activation: 13.3 months).^[31] The investigators reported that at one-year follow-up, assertiveness and responsiveness scores were within the normal range of normal-hearing age-matched peers. Age at cochlear implant activation exerted a significant impact, with the highest scores associated to the youngest patients.

In 2011, Colletti reported on the 10-year results comparing 19 children with cochlear implants received between the ages of 2 to 11 months to 21 children implanted between 12-23 months and 33 children implanted between 24 to 35 months.^[32] Within the first six months post-implantation, there was no significant difference among groups in Category of Auditory Performance testing but differences became significantly better in the infant group (early implantation) at the 12 and 36 month testing. Previously, Colletti reported on findings from 13 infants who had implants placed before 12 months.^[33] The procedures were performed between 1998 and 2004. In this small study, the rate of receptive language growth for these early implant infants overlapped scores of normal-hearing children. This overlap was not detected for those implanted at 12 to 23 or 24 to 36 months.

In 2009 Ching published an interim report on early language outcomes of children with cochlear implants.^[34] This study evaluated 16 children who had implants before 12 months of age compared to 23 who had implants after 12 months (specific time of implantation was not provided). The preliminary results demonstrated that children who received an implant before 12 months of age developed normal language skills at a rate comparable to normal-hearing children, while those with later implants performed at two standard deviations below normal. The authors noted that these results are preliminary, as there is a need to examine the effect of multiple factors on language outcomes and the rate of language development.

Johr (2008) highlighted the surgical and anesthetic considerations when performing cochlear implant surgery in very young infants.^[35] This was an observational study and literature review by pediatricians at a tertiary children's hospital in Switzerland. Surgical techniques and anesthetic management aspects of elective surgeries in small infants were analyzed in patients younger than one year of age undergoing cochlear implant surgeries. The results demonstrated that the age of the patient and the pediatric experience of the anesthesiologist, but not the duration of the surgery, are relevant risk factors. The authors concluded, "Further research is needed to provide more conclusive evidence that the performance outcome for

children implanted before 12 months of age does not converge with the results of children implanted between 12 and 18 months.”

ADULTS AND CHILDREN OVER AGE 12 MONTHS; BILATERAL HEARING LOSS

Since there is sufficient evidence that bilateral and unilateral cochlear implants are safe and lead to improvements in health outcomes in adults and children over the age of twelve months with bilateral severe to profound pre- or postlingual (sensorineural) hearing loss, the evidence reviewed below will be focused on systematic reviews and randomized studies. Nonrandomized studies will not be described in detail.

Systematic Reviews

The following is a summary of the most recent SRs related to CI. These reviews included a critical analysis of the quality of the included studies. While noting the heterogeneity of the studies, and the potential for bias, these reviews found that the studies consistently reported beneficial outcomes for both bilateral and unilateral CI in select children and adults compared with no hearing devices or with conventional hearing aids.

Adults

A technology assessment published by Health Quality Ontario in 2018 evaluated bilateral cochlear implantation in adults and children in separate analyses.^[36] The literature search conducted through March 2017 identified 10 studies on bilateral cochlear implantation in adults: three RCTs and seven prospective observational studies. Two of the three RCTs included data from a single RCT and compared simultaneous bilateral with unilateral cochlear implantation for severe bilateral sensorineural hearing loss. The third RCT randomized 24 adult patients with severe bilateral sensorineural hearing loss to receive bilateral implantation immediately or after a six-month waiting period. The observational studies performed within- or between-patient comparisons of bilateral cochlear implantation with unilateral cochlear implantation with or without hearing aids in the nonimplanted ear. Study quality was evaluated using the GRADE system. The quality of the RCTs was high, medium, and low and the quality of the prospective observational studies ranged from very low to low. The GRADE of evidence for adults overall was rated moderate to high. Overall, the authors concluded that bilateral cochlear implantation improved sound localization, speech perception in noise, and subjective benefits of hearing and that the safety profile was acceptable.

In a meta-analysis, McRackan (2018) examined the impact of cochlear implantation on quality of life (QOL).^[37] From 14 articles with 679 CI patients who met the inclusion criteria, pooled analyses of all hearing-specific QOL measures revealed a very strong improvement in QOL after cochlear implantation (standardized mean difference [SMD]=51.77). Subset analysis of CI-specific QOL measures also showed very strong improvement (SMD=51.69). Thirteen articles with 715 patients met the criteria to evaluate associations between QOL and speech recognition. Pooled analyses showed a low positive correlation between hearing-specific QOL and word recognition in quiet ($r=50.213$), sentence recognition in quiet ($r=50.241$), and sentence recognition in noise ($r=50.238$). A subset analysis of CI-specific QOL showed similarly low positive correlations with word recognition in quiet ($r=50.213$), word recognition in noise ($r=50.241$), and sentence recognition in noise ($r=50.255$) between QOL and speech recognition ability. Using hearing-specific and CI-specific measures of QOL, patients report

significantly improved QOL after cochlear implantation. This study is limited in that widely used clinical measures of speech recognition are poor predictors of patient-reported QOL with CIs.

In a meta-analysis, McRackan (2018) aimed to determine the change in general health-related quality of life (HRQOL) after cochlear implantation and association with speech recognition.^[38] Twenty-two articles met criteria for meta-analysis of HRQOL improvement, but 15 (65%) were excluded due to incomplete statistical reporting. From the seven articles with 274 CI patients that met inclusion criteria, pooled analyses showed a medium positive effect of cochlear implantation on HRQOL (SMD=0.79). Subset analysis of the HUI-3 measure showed a large effect (SMD=0.84). Nine articles with 550 CI patients met inclusion criteria for meta-analysis of correlations between non-disease specific PROMs and speech recognition after cochlear implantation (word recognition in quiet [$r=0.35$], sentence recognition in quiet [$r=0.40$], and sentence recognition in noise [$r=0.32$]). Some limitations are, though regularly used, HRQOL measures are not intended to measure nor do they accurately reflect the complex difficulties facing CI patients. Only a medium positive effect of cochlear implantation on HRQOL was observed along with a low correlation between non-disease specific PROMs and speech recognition. The use of such instruments in this population may underestimate the benefit of cochlear implantation.

In 2013, the authors of the 2011 AHRQ technology assessment reported the following findings of an updated systematic review of studies published through May 2012:^[39]

- Unilateral cochlear implants

Sixteen (of 42) studies were of unilateral cochlear implants. Most unilateral implant studies showed a statistically significant improvement in mean speech scores as measured by open-set sentence or multi-syllable word tests. A meta-analysis of four studies revealed a significant improvement in cochlear-implant relevant quality of life (QOL) after unilateral implantation. However, these studies varied in design and there was considerable heterogeneity observed across studies, making it difficult to compare outcomes across studies.

- Bilateral cochlear implants

Thirteen studies reported improvement in communication-related outcomes with bilateral implantation compared with unilateral implantation and additional improvements in sound localization compared with unilateral device use or implantation only. The risk of bias varied from medium to high across studies. Based on results from at least two studies, the QOL outcomes varied across tests after bilateral implantation. A meta-analysis was not performed because of heterogeneity in design between the studies.

In 2012 and 2013 Crathorne and van Schoonhoven, respectively, published updated SRs for the National Institute for Health and Care Excellence (NICE). Included studies were from the U.S. and Europe and compared bilateral with unilateral cochlear implants. In two studies the unilateral implant group also had an acoustic hearing aid for the contralateral ear. Neither systematic review was able to conduct a meta-analysis due to the heterogeneity of the studies and the level of evidence of the studies which was rated as moderate-to-poor.

In October 2011, Berrettini published results of a systematic review of unilateral and bilateral cochlear implant effectiveness in adults.^[40]

- Unilateral cochlear implants

Eight articles on unilateral cochlear implants in advanced age patients were included. All of the studies reported benefits with cochlear implantation despite advanced age at time of implant (age 70 years or older). In six studies, results were not significantly different between younger and older patients. However, two studies reported statistically significant inferior perceptible results (e.g., hearing in noise test and consonant nucleus consonant test) in older patients. This systematic review also examined three studies totaling 56 adults with pre-lingual deafness who received unilateral cochlear implants. The authors concluded unilateral cochlear implants provided hearing and quality-of-life benefits in prelingually deaf patients, but results were variable.

- Bilateral cochlear implants

Thirteen articles on bilateral cochlear implants were reviewed. Sound localization improved with bilateral cochlear implants compared with monaural hearing in six studies. Significant improvements in hearing in noise and in quiet environments with bilateral implants compared with unilateral implants were reported in ten studies and seven studies, respectively. Five of the studies reviewed addressed simultaneous implantation, five studies reviewed sequential implantation, and three studies included a mix of simultaneous and sequential implantation. However, no studies compared simultaneous to sequential bilateral implantation results, and no conclusions could be made on the timing of bilateral cochlear implantation.

In June 2011 the most recent technology assessment, by the Tufts Evidence-based Practice Center for the Agency for Health Care Research and Quality (AHRQ), reported the following findings on the effectiveness of unilateral and bilateral cochlear implants (CIs) in adults:^[41]

- Unilateral cochlear implants

The assessment examined 22 studies with 30 or more patients and concluded that, while the studies reviewed were rated as poor to fair quality, unilateral cochlear implants are effective in adults with sensorineural hearing loss. Pre- and post-cochlear implant scores on multi-syllable tests and open-set sentence tests demonstrated significant gains in speech perception regardless of whether a contralateral hearing aid was used along with the cochlear implant. Additionally, the assessment found generic and disease-specific health-related quality of life improved with unilateral cochlear implants. However, the available evidence was insufficient to draw conclusions on improvements in open-set sentence test scores (i.e., >40% and ≤50% or >50% and ≤60%), and any relationship between pre-implantation patient characteristics and outcomes [e.g., age, duration of hearing impairment, Hearing in Noise Test (HINT) scores and pre- or post-linguistic deafness.]

- Bilateral cochlear implants

The technology assessment examined 16 studies published since 2004 which were determined to be of fair to moderate quality. The assessment concluded that bilateral cochlear implants provided greater benefits in speech perception test scores, especially in noise, when compared with unilateral cochlear implants with or without contralateral hearing aids. Significant binaural head shadow benefits were noted along with some benefit

in binaural summation, binaural squelch effects, and sound localization with bilateral cochlear implants. However, it was unclear if these benefits were experienced under quiet conditions, although benefits increased with longer bilateral cochlear implant usage indicating a need for longer term studies. Hearing-specific quality of life could not be assessed because only one study evaluated this outcome. Additionally, although gains were experienced in speech perception using open-set sentences or multi-syllable tests compared with unilateral cochlear implants or unilateral listening conditions, the evidence available on simultaneous bilateral implantation was found to be insufficient. The assessment noted longer term studies are needed to further understand the benefits with bilateral cochlear implantation and identify candidacy criteria given the risks of a second surgery and the destruction of the cochlea preventing future medical intervention.

Children

The technology assessment published by Health Quality Ontario in 2018 discussed above regarding its findings on adult implantation identified 14 studies (all prospective observational studies) on bilateral cochlear implantation in children.^[36] Two studies included both sequential and simultaneous bilateral implantation while the rest evaluated sequential only. As for adults, overall, the authors concluded that bilateral cochlear implantation improved sound localization, speech perception in noise, and subjective benefits of hearing and that the safety profile was acceptable (GRADE of evidence: moderate to high). The authors additionally concluded that bilateral cochlear implantation allowed for better language development and more vocalization in preverbal communication in children (GRADE of evidence: moderate).

In a 2015 systematic review, Fernandes evaluated 18 published studies and two dissertations that reported hearing performance outcomes for children with ANSD and cochlear implants.^[42] Studies included four nonrandomized controlled studies considered high quality, five RCTs considered low quality, and 10 clinical outcome studies. Most studies (n=14) compared the speech perception in children with ANSD and cochlear implants with the speech perception in children with sensorineural hearing loss and cochlear implants. Most of these studies concluded that children with ANSD and cochlear implants developed hearing skills similar to those with sensorineural hearing loss and cochlear implants; however, these types of studies do not allow comparisons of outcomes between ANSD patients treated with cochlear implants and those treated with usual care.

In a 2014 systematic review, Lammers summarized the evidence on the effectiveness of bilateral cochlear implantation compared with unilateral implantation among children with sensorineural hearing loss.^[43] The authors identified 21 studies that evaluated bilateral cochlear implantation in children, with no RCTs identified. Due to the limited number of studies, heterogeneity in outcomes and comparison groups, and high risk for bias in the studies, the authors were unable to perform pooled statistical analyses, so a best-evidence synthesis was performed. The best-evidence synthesis demonstrated that there was consistent evidence indicating the benefit of bilateral implantation for sound localization. One study demonstrated improvements in language development, although other studies found no significant improvements. The authors noted that the currently available evidence consisted solely of cohort studies that compared a bilaterally implanted group with a unilaterally implanted control group, with only one study providing a clear description of matching techniques to reduce bias.

In 2013, Eze published a systematic review comparing outcomes for cochlear implantation for children with developmental disability with those without developmental disability.^[44] The

authors noted that while approximately 30% to 40% of children who receive cochlear implants have developmental disability and that evidence about outcomes in this group was limited. Their review included 13 studies that compared receptive or expressive language outcomes in children with cochlear implants with and without developmental disability. The included studies were heterogeneous in terms of comparator groups and outcome measures, precluding data pooling and meta-analysis. In a structured systematic review, the authors reported that seven of the eligible studies demonstrated a significantly poor cochlear implant outcome in children with developmental disability, while the remaining studies reported no significant difference in outcomes between the groups.

Humphriss (2013) published a systematic review evaluating outcomes after cochlear implantation among pediatric patients with auditory neuropathy spectrum disorder (ANSD), a sensorineural hearing disorder characterized by abnormal auditory brainstem response with preserved cochlear hair cell function as measured by otoacoustic emissions testing.^[45] The authors identified 27 studies that included an evaluation of cochlear implantation in patients with ANSD, including 15 noncomparative studies, one that compared children with ANSD who received a cochlear implant with children with ANSD with hearing aids, and 12 that compared children with ANSD who received a cochlear implant with children with severe sensorineural hearing loss who received a cochlear implant. Noncomparative studies were limited in that most (11/15) did not include a measure of speech recognition before cochlear implantation. Among the comparative studies, those comparing cochlear implantation to “usual care”, typically a hearing aid, provided the most information about effectiveness of cochlear implantation among patients with ANSD; the one small study that used this design found no significant differences between the groups. Overall, the authors suggested that further RCT evidence is needed.

Randomized Trials

In 2016, Smulder conducted a small prospective multi-center randomized trial to evaluate the benefits of bilateral implants compared to unilateral implants in adults with postlingual deafness, including 38 patients.^[46] At one-year follow-up, there were no significant differences between groups on the speech-in-noise or the consonant-vowel-consonant test. The bilaterally implanted group performed significantly better when noise came from different directions ($p < 0.001$) and was better able to localize sounds ($p < 0.001$) compared to the unilaterally implanted group. These results were consistent with the patients' self-reported hearing capabilities. The results were consistent at a two year follow up, reported in 2017.^[47]

Nonrandomized Studies

Adults

Numerous case series have been published on adult patients with bilateral cochlear implants.^[48-56] Most but not all studies report slight to modest improvements in sound localization and speech intelligibility with bilateral cochlear implants especially with noisy backgrounds but not necessarily in quiet environments. In addition, depression scores improved in cochlear implant patients from pre-implantation to 12 months post-treatment (geriatric depression scale improvement: 31%, 95% CI 10% to 47%) in a prospective observational study including 113 patients with postlingual hearing loss, of whom 50 were treated with cochlear implants and 63 with hearing aids.^[57]

When reported, the combined use of binaural stimulation improved hearing in the range of one to four decibels or 1 to 2%. While this improvement seems slight, any improvement in hearing can be considered beneficial in the deaf. However, this improvement may not outweigh the significant risks of a second implantation. In addition, similar binaural results can be achieved with a contralateral hearing aid, assuming the contralateral ear has speech recognition ability. A number of studies have reported benefits for patients with a unilateral cochlear implant with hearing aid (HA) in the opposite ear.

Children

Several recent publications have evaluated bilateral cochlear implants in children.^[58-60] These studies, ranging in size from 91 to 961 patients, generally report improved speech outcomes with bilateral implantation, compared with unilateral implantation. In a retrospective case series of 73 children and adolescents who underwent sequential bilateral cochlear implantation with a long (>five year) interval between implants, performance on the second implanted side was worse than the primary implanted side, with outcomes significantly associated with the interimplant interval.^[51, 55, 61-67]

Adults and Children

Ching (2006) subsequently reported on 29 children and 21 adults with unilateral cochlear implant and a contralateral hearing aid.^[49] They noted that both children and adults localized sound better with bilateral inputs.

UNILATERAL HEARING LOSS OR SINGLE SIDED DEAFNESS WITH OR WITHOUT TINNITUS

The FDA has approved the use of two cochlear implant devices in patients with single sided deafness (SSD) or unilateral hearing loss (UHL).

Systematic Reviews

Daher (2023) completed a SR to assess spatial hearing, tinnitus, and quality-of-life outcomes in adults with single-sided deafness (SSD) with cochlear implantation. A total of 36 studies evaluating CI use in 796 unique adults with SSD (51.3 ± 12.4 yr of age at time of implantation) were included. The mean duration of deafness was 6.2 ± 9.6 years. There was evidence of improvement for speech recognition in noise using different target-to-masker spatial configurations, with the largest benefit observed for target-to-masker configurations assessing head shadow (mean, 1.87-6.2 dB signal-to-noise ratio). Sound source localization, quantified as root-mean-squared error, improved with CI use (mean difference [MD], -25.3 degrees; 95% confidence interval [95% CI], -35.9 to -14.6 degrees; $p < 0.001$). Also, CI users reported a significant reduction in tinnitus severity as measured with the Tinnitus Handicap Inventory (MD, -29.97; 95% CI, -43.9 to -16.1; $p < 0.001$) and an improvement in spatial hearing abilities as measured with the Spatial, Speech, and Qualities of Hearing questionnaire (MD, 2.3; 95% CI, 1.7 to 2.8; $p < 0.001$). The authors conclude that CI use offer improvements in speech recognition in noise, sound source localization, tinnitus, and perceived quality of life in adults with SSD.

Idriss (2022) published a SR evaluating the effectiveness of cochlear implants in single-sided deafness with disabling tinnitus when conventional treatments fail to alleviate tinnitus.^[68] A total of 31 studies were included and were divided into two categories according to whether tinnitus was assessed as a primary complaint or not. In all studies, cochlear implantation,

evaluated using subjective validated tools, succeeded in reducing tinnitus significantly. A short- (3 months) and long-(up to 72 months) term tinnitus suppression was reported. When the cochlear implant is disactivated, complete residual tinnitus inhibition was reported to persist up to 24 h. The results followed a similar pattern in studies where tinnitus was assessed as a primary complaint or not. The results followed a similar pattern in studies where tinnitus was assessed as a primary complaint or not. The authors conclude that cochlear implantation is effective in reducing disabling tinnitus in single-sided deafness patients. The studies included were mostly observational, there was heterogeneity of assessment tools used and a small sample size.

Oh (2022) reported on a SR and meta-analysis of cochlear implantation in adults with single-sided deafness.^[69] A total of 50 studies with 674 patients (3 to 45 patients meeting inclusion criteria per study) were included. Of these, 41 were prospective cohort studies, seven were retrospective cohort studies, and two were case series. A meta-analysis of speech perception outcomes, which included five studies, found a standardized mean difference (SMD) post-versus pre-implantation of 2.8 (95% CI 2.16 to 3.43), with some evidence of publication bias. A meta-analysis of QoL, which included eight studies, found a significant improvement, with an SMD of 0.68 (95% CI 0.45 to 0.91), and no evidence of publication bias. Meta-analysis of sound localization (seven studies; SMD, -1.13 [95% CI -1.68 to -0.57]), and tinnitus score reduction (seven studies; SMD -1.32 [95% CI -1.85 to -0.80]) also reported significant improvements. Limitations include the small sample sizes of included studies, imprecise definitions of single-sided deafness used across studies, and heterogeneity in outcomes measured, follow-up time frames, and etiology of single-sided deafness.

Donato (2021) published a SR with meta-analysis evaluating the efficacy of bone conduction devices and cochlear implantation in single-sided deafness, through the evaluation of speech discrimination in noise, sound localization and tinnitus suppression.^[70] As a secondary outcome, patient satisfaction is also assessed. Nineteen articles with a total of 210 patients (95 patients with bone conduction devices and 115 in the cochlear implantation group) were included. Both children and adults were included. Sound localization was significantly better with CI with an average improvement of 13.9 degrees compared to an average of 2.31 degrees with BCD. For tinnitus, symptoms were decreased an average of 37.97 points for CI patients and decreased an average of 9.89 points for patients with BCD. The CI group reported statistically significant improvements overall, in ease of communication, and in reverberation subscales. The BCD group reported statistically significant improvements for sound discrimination in noise. The authors conclude that both CI and bone conduction devices are effective in patients with single sided deafness. They also suggest that BCD should continue to be considered in the treatment of these patients because patient satisfaction is greater in environments with background noise. And that BCD is associated with a faster and more comfortable rehabilitation process.

Assouly (2021) published a systematic review of cochlear implantation for tinnitus.^[71] A total of seven prospective cohort studies, with 105 total subjects (range 10 to 26) met inclusion criteria. Two studies had a moderate risk of bias and five had serious risk of bias. Due to considerable methodological and statistical heterogeneity ($I^2 > 75\%$), no meta-analysis was performed. Each included study reported a statistically significant improvement in tinnitus distress (measured via questionnaire). The only reported adverse event was worsening of tinnitus loudness following implantation in one participant.

Benchetrit (2021) published a systematic review and meta-analysis evaluating audiological and patient-reported outcomes in children <18 years with single-sided deafness (SSD).^[72] Twelve observational studies evaluating 119 children (mean age [standard deviation], 6.6 [4.0] years) were included. Clinically meaningful improvements in speech perception in noise (39/49 [79.6%]) and in quiet (34/42 [81.0%]) were reported. Sound localization improved significantly following implantation (mean difference [MD], -24.78°; 95% CI, -34.16° to -15.40°; I² = 10%). Compared to patients with congenital SSD, patients with acquired SSD and shorter duration of deafness reported greater improvements in speech and hearing quality. Patients with longer duration of deafness were also more likely to be device nonusers (MD, 6.84; 95% CI, 4.02 to 9.58).

A health technology assessment was published in 2020 to evaluate clinical benefits and harms, cost-effectiveness, budget impact, and patient preferences and values related to implantable devices for single-sided deafness and conductive or mixed hearing loss.^[73] For adults and children with single-sided deafness, cochlear implantation when compared with no treatment improves speech perception in noise (% correct responses: 43% vs. 15%, $p < .01$; moderate grade), sound localization (localization error: 14° vs. 41°, $p < .01$; moderate grade), tinnitus (Visual Analog Scale, loudness: 3.5 vs. 8.5, $p < .01$; moderate grade), and hearing-specific quality of life (Speech Spatial and Qualities of Hearing Scale, speech: 5.8 vs. 2.6, $p = .01$; spatial: 5.7 vs. 2.3, $p < .01$; moderate grade); for children, speech and language development also improve (moderate grade). The authors conclude that based on evidence of moderate quality, cochlear implantation implants and bone-conduction implants improve functional and patient-important outcomes in adults and children with single-sided deafness and conductive or mixed hearing loss. And that among people with single-sided deafness, cochlear implants may be cost-effective compared with no intervention, but bone-conduction implants are unlikely to be.

Levy (2020) published a systematic review of cochlear implantation for tinnitus in SSD.^[74] A total of 17 studies including 247 patients met inclusion criteria. The mean age was 50.2 years (range 23 to 71). Tinnitus outcomes were measured using the Tinnitus Handicap Inventory (THI). Based on six studies, an improvement of 35.4 points (95% CI -55.8 to -15.0, $p < 0.001$) was reported. Based on 13 studies reporting on subjective improvement, with proportions weighted based on patients per study, 14.9% (CI 6.4 to 26.1) of patients reported complete resolution of tinnitus, 74.5% (CI 63.1 to 84.5) reported partial improvement; 7.6% (CI 4.1 to 12.6) of patients had no change in severity, and 3.0% (CI 1.0 to 6.7) reported worsening of their tinnitus.

A 2019 SR published by Peter identified 13 studies that met inclusion criteria and evaluated the influence of cochlear implantation on tinnitus in patients with single-sided deafness.^[75] All identified studies were cohort studies. They mainly reported tinnitus questionnaire scores using the THI. Overall, of the 153 included patients, 34.2% demonstrated complete suppression, 53.7% demonstrated an improvement, 7.3% demonstrated a stable value, and 4.9% showed an increase of tinnitus. No patients reported an induction of tinnitus.

Peters (2016) and Cabral (2016) published SRs evaluating the effectiveness of cochlear implants in all ages^[76] and in children^[77] with unilateral hearing loss. Both reviews were inconclusive as there was significant clinical heterogeneity within the studies, primarily prospective or case series studies with small sample sizes, and the lack of high level of evidence. Both indicate the need for further research.

In 2015, van Zon published a systematic review of studies evaluating cochlear implantation for single-sided deafness or asymmetric hearing loss.^[78] The authors reviewed 15 studies, nine of which (n=112 patients) were considered high enough quality to be included in data review. The authors identified no high-quality studies of cochlear implantation in this population. Data were not able to be pooled for meta-analysis due to high between-study heterogeneity, but the authors conclude that studies generally report improvements in sound localization, quality of life scores, and tinnitus after cochlear implantation, with varying results for speech perception in noise.

In 2014, Vlastarakos published a systematic review of the evidence related to cochlear implantation for single-sided deafness.^[79] The authors included 17 studies, including prospective and retrospective comparative studies, case series and case reports that included 108 patients. The authors report that sound localization is improved after cochlear implantation, although statistical analysis was not included in some of the relevant studies. In most patients (95%), unilateral tinnitus improved. The authors note that most of the studies included had short follow-up times, and evaluation protocols and outcome measurements were heterogeneous.

In 2014, Blasco and Redleaf published a systematic review and meta-analysis of studies evaluating cochlear implantation for unilateral sudden deafness.^[80] The review included nine studies with a total of 36 patients. In pooled analysis, subjective improvement in tinnitus occurred in 96% of patients (of 27 assessed), subjective improvement in speech understanding occurred in 100% of patients (of 16 assessed), and subjective improvement in sound localization occurred in 87% of patients (of 16 assessed). However, the small number of patients in which each outcome was assessed limits any conclusions that may be drawn.

Randomized Trials

Marx (2021) conducted a small open-label, multicenter RCT of cochlear implantation (n=25) versus initial observation and treatment abstention (n=26) in adult patients with single-sided deafness or asymmetric hearing loss following failure of prior treatment with contralateral routing of the signal (CROS) hearing aids or bone-conduction devices.^[81] Primary outcomes included HRQOL, auditory-specific quality of life, and tinnitus severity as assessed after six months of treatment. Both EQ-5D visual analog scale and auditory-specific quality of life indices significantly improved in the cochlear implant arm. However, no significant difference in overall EQ-5D descriptive component scores were noted between groups. Mean improvement was most pronounced in subjects with associated severe tinnitus. A clinical rationale for the minimum clinical improvement in quality of life (0.8 SD) was not reported. No significant difference for speech recognition in noise or horizontal localization was noted between groups at six months, indicating no significant effect on binaural hearing within this timeframe.

Peters (2021) randomized 120 adults with single-sided deafness (median duration, 1.8 years) into three treatment groups for the "Cochlear Implantation for siNGLE-sided deafness" (CINGLE) trial: cochlear implant (n=29); first bone-conduction devices, then CROS (n=45); and first CROS, then bone-conduction devices (n=46).^[82] Patients with a maximum 30 dB hearing loss in the best ear and a minimum 70 dB hearing loss in the poor ear with duration of single-sided deafness between 3 months and 10 years were eligible for inclusion. After the initial cross-over period, 25 patients were allocated to bone-conduction devices, 34 patients were allocated to CROS, and 26 patients preferred no treatment. Seven patients did not receive their allocated treatment. For the primary outcome, speech perception in noise from the front, a

statistically significant improvement was noted for the cochlear implant group at three and six months compared to baseline. At three months follow-up, the cochlear implant group performed significantly better than all other groups. At six months, the cochlear implant group performed significantly better than the bone-conduction devices and no treatment groups but no significant difference was observed between the cochlear implant group and the CROS group. Sound localization improved in the cochlear implant group only. All treatment groups improved on disease-specific quality of life compared to baseline. The study is limited by small sample size, device heterogeneity, loss to follow-up, and lack of allocation concealment. Study follow-up through five years is ongoing.

Nonrandomized Studies

Arras (2022) published a study comparing spatial hearing skills in children (n=47) across three groups: 12 SSD + CI (median age 4.7 years, range 3.9 to 7.7 years), 9 SSD-no CI (median age 4.8 years, range 3.9 to 7.0 years), and 26 normal hearing (median age 5.3 years, range 3.9 to 8.1 years).^[83] Most SSD + CI children had approximately 3 years of experience with their CI at the time of their first assessment (median time 3.1 years). Only the child with acquired SSD had less than 2.5 years of experience with the device when first tested (1.9 years). The authors conclude that the implanted group exhibited improved speech perception in noise abilities and better sound localization skills, compared to their non-implanted peers. On average, the children wore their device approximately nine hours a day. They recommend further follow-up to understand the long-term benefit of a cochlear implant for children with prelingual SSD. The study is limited sample size and heterogeneity of the participant groups.

Brown (2022) published results from the Childhood Unilateral Hearing Loss (CUHL) prospective, single-arm trial.^[84] Twenty children aged 3-12 with moderate to profound sensorineural hearing loss and poor speech perception (word score <30%) in one ear and normal hearing in the contralateral ear were enrolled. CNC word score perception in quiet improved significantly from 1% to 50% ($p<.0001$) at 12 months after activation. Speech perception in noise by BKB-SIN score also significantly improved by 3.6 dB in head shadow ($p<.0001$), 1.6 dB in summation ($p=.003$), and 2.5 dB in squelch ($p=.0001$). By 9 months, localization improved by 26°. Significant improvements were also found in SSQ speech ($p=.0012$), qualities of hearing ($p=.0056$), and spatial hearing subscales ($p<.0001$). Improvements in fatigue were not statistically significant. Study limitations include use of a single-arm study design, small sample size, and incomplete comparison to best-aided hearing at baseline, including enrollment of never aided subjects.

In January of 2022, the FDA approved to expand the indication for the Nucleus 24 Cochlear Implant system to include individuals aged five years and older with single-sided deafness (SSD) or asymmetric hearing loss (AHL).^[85] Data were combined from a feasibility study (n=10) and RWE (n = 32) conducted across four sites. There were 23 subjects with post-operative data available for the first co-primary endpoint, and 38 with data available for the second co-primary endpoint. The authors concluded that the effectiveness data demonstrated that for most subjects, the cochlear implant provided clinical benefit both in noise and with localization.

Benitez (2021) conducted a retrospective case review study to determine the effect of CI in patients with SSD of different age groups.^[86] Twenty-three post-lingually deaf children (ages 6-12 years) and 21 adult patients with single-side deafness were included. The authors reported the results as follows: In children the most common etiology was idiopathic sensory-neural

hearing loss. Children showed positive results in the Auditory Lateralization Test. In the Speech Test, word recognition in noise improved from 2% preoperatively to 61.1% at a mean follow-up of 1 year (S0 condition) in children [test with signal in CI side 60% and signal normal hearing side (plugged) 31%]. For adults, the most common etiology was idiopathic sudden sensorineural hearing loss (SNHL). Positive results in the Auditory Lateralization Test were found. With respect to the Speech Test in quiet conditions: Word recognition in noise improved from 5.7% preoperatively to 71.8% at a mean follow-up of 1 year [test with signal in CI side 68% and signal normal hearing side (plugged) 41%]. No adverse events were reported during the study period. No differences were found between children and adults in all tests in this study. The authors conclude that Cochlear implantation in post-lingually deaf adults and children with SSD can achieve a speech perception outcome comparable with CI in conventional candidates. They also note that careful patient selection and counseling regarding potential benefits are important to optimize outcomes.

Rauch (2021) published the results of a retrospective study to investigate the audiological improvement, subjective benefit (parents/caregivers and children), identify long-term non-users outcome and identify critical age of cochlear implantation in congenital SSD.^[87] Children (n=11) with congenital SSD were implanted with a CI. The authors report that nine children use their CI (> 8 h/day) and two became nonusers. In children aged below 3 years and 2 months at surgery, there was a substantial long-term increase in speech discrimination and subjective benefit. Children over 4 years and 4 months at CI surgery improved partially in audiological/subjective measurements. Among children above 5 years, the SSQ score did not improve despite further slight improvement in speech discrimination long-term. The authors conclude a critical age for CI surgery below 3 years in children with congenital SSD for successful hearing rehabilitation.

Poncet-Wallet (2020) conducted a multicentered prospective, non-randomized intervention study to investigate the audiological and tinnitus outcomes of cochlear implantation (CI) in adults with single-sided deafness (SSD) and tinnitus.^[88] Twenty-six patients (from six clinics) with SSD and incapacitating tinnitus (Tinnitus Handicap Inventory [THI] >58) underwent cochlear implantation. The first month of white noise stimulation triggered a significant improvement in THI scores (72 ± 9 to 55 ± 20 , $p < 0.05$). After 1 year of standard CI stimulation, 23 patients (92%) reported a significant improvement in tinnitus. This improvement started 1 to 2 months after CI and exceeded 40% improvement for 14 patients (54%). Average speech-in-noise perception after 1 year significantly improved for the 23 patients who completed these measures. The authors conclude that CI is efficacious to reduce the handicap of patient with SSD and incapacitating tinnitus, leading to a decrease in reported tinnitus and partial restoration of binaural hearing abilities.

Dillon (2020) conducted a prospective clinical trial evaluating 20 subjects with asymmetric hearing loss (AHL), defined as a hearing loss of ≥ 70 dB HL in the ear to be implanted and between 35 and 55 dB HL in the contralateral ear.^[89] Patients were required to fail initial treatment with traditional or bone-conduction hearing aids. Subjects underwent cochlear implantation with the MED-EL Synchrony Standard electrode array. Significant subjective benefit was reported by patients within one month of implantation. At the 12-month interval, spatial hearing localization was significantly improved ($p < 0.001$). Masked sentence recognition was found to improve at the 12-month interval in the SoNcontra configuration ($p < 0.001$), but there was no significant difference in the SoNo or SoNci spatial configurations. Subjects demonstrated a significant improvement in CNC word recognition between one and six months ($p = 0.002$) and 6 and 12 months ($p = 0.010$). Findings were compared with previously published

data for patients in the unilateral hearing loss cohort of this study.^[90] Significant main effects of cohort were found for localization performance and spatial configuration in masked sentence recognition, indicating that the magnitude of benefit for these outcomes was reduced for subjects with AHL.^[89] In 2019, Dillon published a clinical update reporting on the prevalence of low-frequency hearing preservation with the use of standard long electrode arrays (MED-EL Corporation) in a subset of 25 patients (12 with unilateral hearing loss) from earlier cohorts.^[91] Unaided hearing thresholds at 125 Hz were compared between the preoperative and initial activation intervals in 24 participants to assess the change in low-frequency hearing. At activation, a significant elevation in the unaided hearing thresholds at 125 Hz was noted ($p < 0.001$), with the majority of subjects ($n = 16$) demonstrating no response to stimulus. The remaining nine participants maintained an unaided low-frequency hearing threshold of ≤ 95 dB, and 5/9 participants met the fitting criterion of ≤ 80 dB for electric-acoustic stimulation (EAS) at initial activation. An additional three participants demonstrated improvement in unaided low-frequency hearing thresholds at latter monitoring intervals. It is uncertain whether identifying patients with preservation of low-frequency hearing can help predict individuals that may benefit from EAS vs standard cochlear implants.

Galvin III (2019) reported data from an FDA-approved study of cochlear implantation in 10 patients with SSD.^[92] Patients were implanted with the MED-EL Concerto Flex 28 device. Speech perception in quiet and noise, localization, and tinnitus severity were measured prior to implantation at one, three, and six months postactivation. Performance was assessed with both ears (binaural), with the implanted ear alone, and the normal hearing alone. No patient had previous experience with a contralateral routing of signal (CROS) or bone conduction device (BCD) system. Mean improvement for consonant-nucleus-consonant (CNC) word recognition vs baseline was 66.8%, 76.0%, and 84.0% at one, three, and six months postactivation, respectively. The normal hearing ear performed significantly better compared to the implanted ear for all outcome measures at all intervals ($p < 0.05$). Audiological performance of the implanted ear at one, three, and six months postactivation was significantly better compared to baseline ($p < 0.05$), with no significant difference across postactivation intervals ($p > 0.05$). The change in root mean square error (RMSE) in localization with binaural listening postactivation reduced by 6.7, 7.6, and 11.5 degrees at one, three, and six months postactivation. Binaural performance was significantly improved compared to the normal hearing ear alone at all postactivation time intervals ($p < 0.05$). Tinnitus visual analog scale (VAS) scores significantly decreased with the implant on at all postactivation time intervals ($p < 0.05$). Significant improvements on SSQ scores were reported for the Speech ($p = 0.003$), Spatial ($p < 0.001$), and Quality ($p = 0.034$) subtests. Global scores were not reported. Adverse events were reported in 5/10 participants, including facial nerve stimulation, periorbital edema, mild postoperative balance disturbance, postauricular pain, and unresolved taste disturbance. The study is limited by small sample size.

Peter (2019) published the results of a Swiss multicenter study assessing cochlear implantation for use in adult patients in post-lingual single-sided deafness, defined as a hearing loss of 70 dB hearing level (HL) in the mean thresholds of 0.5, 1, 2, and 4 kHz in the affected ear, and 25 dB HL or better in the frequencies from 125 to 2 kHz and 35 dB HL or better from 4 to 8 kHz in the normally hearing contralateral ear.^[93] A total of 10 patients were evaluated. Two years post-implantation, 90% of patients used their implant regularly for an average of more than 11 hours per day. Twelve months postactivation, speech from the front and noise at the healthy ear achieved a 2.7 dB improvement ($p = 0.0029$). Speech to the implanted ear and noise from the front achieved a 1.5 dB improvement ($p = 0.018$). The mean sound localization error of all participants was improved by 10.2 degrees ($p = 0.030$) at 12

months postactivation. One participant experienced a loss in low-frequency residual hearing from surgery, resulting in poorer localization performance after surgery with an increased error of 11.3 degrees. Tinnitus severity decreased significantly 12 months postactivation from 41.2 points (SD 26.5) preoperatively to 23.0 points (SD 17.5; $p=0.004$) on the Tinnitus Handicap Inventory (THI). Quality of life measures showed a significant improvement on the global subscale of the WHO Quality of Life questionnaire ($p=0.007$). The Speech, Spatial, and Qualities of Hearing Scale questionnaire (SSQ) indicated a significant improvement from 4.2 to 6 ($p=0.004$) in speech comprehension and from 3 to 5.3 ($p=0.009$) in spatial hearing. No significant difference was noted in the subscale qualities of hearing (6.2 to 6.9; $p=0.13$). The scores of the patients on the three subscales were significantly lower than for the normal hearing control group, with an average speech comprehension score of 8.7 ($p=0.001$), an average spatial hearing of 8.6 ($p<0.001$), and an average qualities of hearing score of 9.1 ($p=0.005$). Adverse events were not reported.

In July 2019, the FDA approved to expand the indication for the MED-EL Cochlear Implant System to include individuals aged five years and older with single-sided deafness (SSD) or asymmetric hearing loss (AHL).^[94] Approval was based on supporting evidence from a comprehensive literature review and a clinical feasibility study conducted at one site. In this prospective, non-blinded, repeated measures study, 40 subjects were implanted with the MED-EL CONCERT or SYNCHRONY Cochlear Implant System. Twenty patients each were enrolled into the SSD and AHL groups. All 20 patients completed testing in the SSD group. One patient withdrew from the AHL group and one patient had not yet completed follow-up at the time of data analysis. Patients were required to have previous experience of at least one month in duration with a conventional hearing aid, bone conduction device, or CROS device. Exclusion criteria included Meniere's disease with intractable vertigo, tinnitus as the primary concern for cochlear implantation, and severe or catastrophic score on the THI. Aided word recognition in the ear to be implanted was required to be 60% or less as measured with a 50-word CNC word list. Speech perception and localization were evaluated at baseline and at 1, 3, 6, 9, and 12 months post-operatively utilizing CNC word recognition and AzBio sentence tests. For patients in the AHL group, sound field testing was completed with a hearing aid in the contralateral ear. Quality of life measures included the SSQ, THI, and Abbreviated Profile of Hearing Aid Benefit (APHAB) scales. Primary effectiveness measures were comparisons of speech perception and localization performance between the bilateral, preoperative, unaided/best-aided condition and the bilateral, 12-month post-operative cochlear implant (CI) + normal hearing (NH) or hearing aid (HA) condition. Nine device or procedure related adverse events were reported. Most frequently reported adverse events included vertigo/dizziness/imbalance (22.5%) and unrelated infection (7.5%). The data is limited by small sample size and including only adult subjects only and the effectiveness endpoints were not prespecified. Given these limitations, the clinical data collected from the UNC study are not sufficient on their own to support the generalization of the clinical outcomes to the proposed, intended adult and pediatric populations, and support the requested SSD/AHL indication expansion.

The FDA decision was further supported by a literature search yielding six publications comprising a total of 58 adults with SSD ($n=50$ of which implanted with MED-EL devices) and a total of 52 adults with AHL ($n=37$ of which implanted with MED-EL devices).^[95] The candidacy criterion of ages five and older was based on a literature search yielding five publications comprising a total of 26 children with SSD ($n=5$ of which implanted with a MED-EL device) and a total of nine children with AHL. While the overall benefits of CI in children with SSD and AHL included improved performance in speech perception in quiet and noise, sound localization,

and subjective measures of quality of life – these results are limited to primarily case series with small sample sizes, heterogeneous in methodology and outcome assessment, and at high risk of bias in self-reported measures. The FDA has required MED-EL to conduct a post-marketing study to continue to assess the safety and efficacy of the implant in a new enrollment cohort of adults and children.

Buss (2018) published the results of an FDA clinical trial that investigated the potential benefit of cochlear implant (CI) for use in adult patients with moderate-to-profound unilateral sensorineural hearing loss and normal to near-normal hearing on the other side.^[90] The study population was 20 CI recipients with one normal or near-normal ear (NH) and the other met criterion for implantation (CI). All subjects received a MED-EL standard electrode array, with a full insertion based on surgeon report. They were fitted with an OPUS 2 speech processor. This group was compared to 20 normal hearing persons (control group) that were age-matched. Outcome measures included: sound localization on the horizontal plane; word recognition in quiet with the CI alone, and masked sentence recognition when the masker was presented to the front or the side of normal or near-normal hearing. The follow-up period was 12-months. While the majority of CI recipients had at least one threshold ≤ 80 dB prior to implantation, only three subjects had these thresholds after surgery. For CI recipients, scores on consonant-nucleus-consonant (CNC) words in quiet in the impaired ear rose an average of 4% (0 to 24%) at the postoperative test to a mean of 55% correct (10 to 84%) with the CI alone at the 12-month test interval.

Arndt (2017) published a single center cohort study to provide evidence of successful treatment of SSD and asymmetric hearing loss with a CI compared to the untreated, monaural hearing condition and the therapy options of brain computer interface (BCI) and contralateral routing of signals (Bi)CROS devices.^[96] A total of 85 patients (45 with SSD and 40 patients with asymmetric hearing loss) were treated with a CI. Monaural speech comprehension in noise and localization ability were examined with (Bi)CROS-Hearing Aid and BCI devices (on a test rod) both preoperatively and at 12 months after CI switch-on. At the same intervals, subjective evaluation of hearing ability was conducted using the Speech, Spatial and Qualities of Hearing Scale (SSQ). The authors report that binaural rehabilitation with CI was successful. Also, patients with long-term acquired deafness (>10 years) demonstrated a benefit from CI comparable to that observed in patients with shorter-term deafness.

A 2016 study from Sladen reported on a retrospective review of prospectively-collected data of short-term (six-month) follow-up for 23 adults and children with single-sided deafness from a variety of mechanisms who received a cochlear implant.^[97] In the implanted ear, CNC word recognition improved significantly from pre-implantation to three months post-activation ($P=0.001$). However, for AzBio sentence understanding in noise (+5 dB signal-to-noise [SNR]), there was no significant improvement from pre-implantation to six months post-activation.

Also in 2016, Rahne reported on a retrospective review of four children and 17 adults with single-sided deafness treated with cochlear implants and followed for 12 months.^[98] Sound localization with aided hearing improved from pre-implantation to aided hearing for all individuals. The Speech recognition threshold in noise (signal-to-noise) ratio improved from -1.95 dB (CI off, SD: 2.7 dB) to -4.0 dB after three months (SD 1.3 dB, $P<0.05$), with continued improvements through six months.

In 2016, Mertens reported a case series including 23 individuals who received cochlear implants for single-sided deafness with tinnitus.^[99] Eligible patients had either single-sided

deafness or asymmetric hearing loss and ipsilateral tinnitus. Subjects had a mean eight years of experience with their cochlear implant (range, 3 to 10 years). Patients demonstrated improvements in VAS from baseline (mean score, 8) to one month (mean score: 4; $p < 0.01$ vs baseline) and three months (mean score: 3; $p < 0.01$ vs baseline) after the first fitting. Tinnitus scores improved from baseline to three months post fitting (55 vs 31, $p < 0.05$) and were stable for the remainder of follow-up.

In 2015, Ramos Macias reported results of a prospective multicenter study with repeated measures related to tinnitus, hearing, and quality of life, among 16 individuals with unilateral hearing loss and severe tinnitus who underwent cochlear implantation.^[100] All patients had a severe tinnitus handicap (THI score $\geq 58\%$). Eight (62%) of the 13 patients who completed the six-month follow-up visit reported a lower tinnitus handicap on the THI score. Perceived loudness/annoyingness of the tinnitus was evaluated with a 10-point VAS. When the CI was on, tinnitus loudness decreased from 8.4 preoperatively to 2.6 at the six-month follow-up; 11 of 13 patients reported a change in score of three or more.

In 2015, Arndt reported outcomes for 20 children who underwent cochlear implantation for single-sided deafness, which represented a portion of their center's cohort of 32 pediatric patients with single-sided deafness who qualified for cochlear implants.^[101] Repeated-measure analyses of hearing data sets were available for 13 implanted children, excluding five who had undergone surgery too recently to be evaluated and two children who were too young to be evaluated for binaural hearing benefit. There was variability in the change in localization ability across the tested children. Self- (or child-) reported hearing benefit was measured with the Speech, Spatial and Qualities of Hearing Scale (SSQ). Significant improvements were reported on the child and parent evaluations for the scale's three subcategories: speech hearing, spatial hearing, hearing quality, and total hearing.

In 2013, Hansen reported results of a prospective study of cochlear implantation for severe-to-profound single-sided sensorineural hearing loss in 29 patients, 10 of whom had single-sided deafness due to Meniere's disease.^[102] Performance was compared pre- to post-implant within each subject; outcomes were measured at three-, six-, and 12-months postoperatively. Patients showed significant improvements in CNC word and AzBio sentence scores showed improvement in the implanted ear pre-and post-implant. For the 19 patients with pre- and post-operative data available, the average improvement on CNC word score was 28% (range: -26% to 64%). The average AzBio score improvement was 40% (range: -57% to 92%).

Tavora-Vieira (2013) reported results of a prospective case series that included nine post-lingually deaf subjects with unilateral hearing loss, with or without tinnitus in the ipsilateral ear, with functional hearing in the contralateral ear, who underwent cochlear implantation.^[103] Speech perception was improved for all subjects in the "cochlear implant on" state compared with the "cochlear implant off" state, and subjects with tinnitus generally reported improvement.

Section Summary

The available evidence for the use of cochlear implants in improving outcomes for patients with single sided deafness or unilateral hearing loss, with or without tinnitus includes SRs, open label RCTs with small sample sizes, two feasibility studies, prospective and retrospective studies, and two guidelines (one for adults and one for children). The FDA recently approved two devices for cochlear implantation for UHL or SSD. Two feasibility studies with single-sided deafness or asymmetric hearing loss demonstrated improvements in sound perception, sound localization, and subjective measures of quality of life compared to baseline conditions.

Although data is limited to small sample sizes and heterogeneity of methodology and outcome measures, the use of cochlear implant in SSD or UHL may improve outcomes such as speech recognition in noise, sound source localization, tinnitus, and perceived quality of life in some patients.

Cochlear Restoration

The optimal timing of cochlear implantation in children is of particular interest given the strong associations between hearing and language development. While there is current research investigating the ability to restore hearing by stimulating cochlear hair cell regrowth, cochlear implantation damages the cochlea and eliminates the possibility of cochlear restoration. However, the potential to restore cochlear function is not foreseeable in the near future; therefore, if implantation of cochlear implants is felt to be most beneficial at a younger age when the nervous system is “plastic”, this potential development seems too far in the future to benefit young children who are current candidates for a cochlear implant.

HYBRID COCHLEAR IMPLANTATION

Systematic Review

Santa Maria (2014) conducted a systematic review and meta-analysis of hearing outcomes after various types of hearing-preservation cochlear implantation, including implantation hybrid devices, cochlear implantation with surgical techniques designed to preserve hearing, and the use of post-operative systemic steroids.^[104] The study included 24 studies, but only two studies focused specifically on a hybrid cochlear implant system, and no specific benefit from a hybrid system was reported.

Nonrandomized Studies

The pivotal trial for the Med-EL EAS system was a prospective, multi-center, non-randomized, non-blinded, repeated measures clinical study of 73 subjects at 14 U.S. sites, implanted with either SONATA FLEX24 or a PULSAR FLEX24.^[4] Final outcomes were reported in 2018 by Pillsbury.^[105] Sixty-seven of 73 subjects (92%) completed outcome measures at 3, 6, and 12 months postactivation. A 30 dB or less low-frequency pure-tone average shift was experienced by 79% and 97% were able to use the acoustic unit at 12 months postactivation. In the EAS condition, 94% of subjects performed similarly or demonstrated improvement (85%) compared to preoperative performance on City University of New York sentences in noise at 12 months. Ninety-seven percent of subject performed similarly or improved (85%) on CNC words in quiet. Improvements in speech perception scores were statistically significant ($p < 0.001$). The Abbreviated Profile of Hearing Aid Benefit (APHAB) was administered preoperatively and at 12 months postactivation; 60 subjects completed the APHAB assessment at each time point. The mean score on the APHAB Global Scale improved by 30.2%, demonstrating a significant reduction in perceived disability ($p < 0.001$). Thirty-five device-related adverse events were reported for 29 of 73 subjects (39.7%). The most frequently observed adverse event was profound/total loss of residual hearing, which occurred in 8 of 73 subjects (11.0%).

The pivotal trial for the Nucleus® Hybrid™ L24 Cochlear Implant System, published by Roland in 2016, was a prospective, multi-center, one-arm, non-randomized, non-blinded, repeated-measures clinical study of 50 subjects at 10 U.S. sites.^[106] Performance was compared pre- to post-implant within each subject; outcomes were measured at three-, six-, and 12-months postoperatively. Post-operatively, patients' hearing was evaluated in three states: Hybrid

(simultaneous electric and acoustic stimulation in the implanted ear via the Hybrid L24 including the acoustic component), Bimodal (electric stimulation only using the Hybrid L24 minus the acoustic component with contralateral acoustic stimulation), and Combined (electric and acoustic stimulation via the Hybrid L24 and contralateral acoustic stimulation). Results from the Bimodal and Combined conditions were grouped into an “Everyday Listening” category, which was not prospectively defined by the manufacturer. All 50 subjects enrolled underwent device implantation and activation. One subject had the device explanted and replaced with a standard cochlear implant between the three- and six- month follow up visit due to profound loss of low frequency hearing; an additional subject was explanted before the 12-month follow up visit and two additional subjects were explanted after 12 months. For the two primary effectiveness endpoints, CNC word-recognition score and AzBio sentence-in-noise score, a measure of sentence understanding in noisy environments, there were significant within-subject improvements from baseline to six-month follow up. The mean improvement in CNC word score was 35.7% (95% confidence interval [CI] 27.8% to 43.6%); for AzBio score, the mean improvement was 32.0% (95% CI 23.6% to 40.4%) For safety outcomes, 71 adverse events were reported, most commonly profound/total loss of hearing (occurring in 44% of subjects) with at least one adverse event occurring in 34 subjects (68%).

Five-year outcomes for the pivotal trial were reported by Roland in 2018.^[107] Thirty-two out of 50 subjects (64%) enrolled in the postapproval study. Out of the 18 subjects who did not participate, six had been explanted and reimplanted with a long electrode array, two discontinued for unrelated medical reasons, two withdrew for other reasons, four declined to continue follow-up evaluations, and four chose not to participate in the postapproval study. At five years postactivation, 94% of subjects had measurable hearing and 72% continued to use electric-acoustic stimulation with functional hearing in the implanted ear, and 6% had a total loss. Changes from pre-operate hearing to six months were statistically significant ($p < 0.001$), but changes six months through five years postactivation were not statistically different ($p > 0.05$). Acoustic component amplification was utilized by 84% and 81% of patients at 12 and three years postactivation, respectively. Mean CNC word recognition in quiet scores were significantly improved over the preoperative condition at each postactivation interval ($p < 0.001$). However, mean scores did not significantly differ after 12 months postactivation. At five years postactivation, 94% performed the same or better in unilateral CNC word scores, whereas 6% demonstrated a decline in performance. For bilateral CNC word scores, 97% performed the same or better, whereas one subject showed a decline in performance. The Speech, Spatial, and Qualities of Hearing Questionnaire (SSQ) was implemented to measure subjective implant satisfaction and benefit. Scores significantly improved and remained stable through all postactivation intervals ($p < 0.001$).

In 2016, Gantz published outcomes from a multicenter, longitudinal study evaluating outcomes with the Nucleus Hybrid S8 featuring a shorter cochlear array.^[108] Eighty-seven subjects received an implant. At 12 months postactivation, five subjects had total hearing loss, whereas functional hearing was maintained by 80%. CNC word scores demonstrated 82.5% of subjects had experience a significant improvement in the hybrid condition. Improvement in speech understanding in noise were demonstrated in 55% of subjects. Fourteen patients requested implant explantation due to various reasons of dissatisfaction with the device. These patients were re-implanted with a standard-length Nucleus Freedom cochlear implant. CNC scores prior to loss of residual hearing were missing for six subjects. CNC scores following re-implantation were missing for two additional subjects. Similar or better CNC scores following re-implantation were observed in five of the six remaining subjects.

In 2015, Friedmann conducted a retrospective review that included 22 subjects implanted with a cochlear implant with either a standard electrode (n=12) or the Nucleus Hybrid L24 electrode (n=10).^[109] At one year post-implant, 30% patients with the Hybrid-L and 58% patients with the standard electrode lost residual acoustic hearing resulting in a profound hearing loss in the implanted ear. The authors reported that while hearing preservation rates with the hybrid electrode tended to be better, among recipients who lost residual hearing, speech perception was better in those with the longer standard electrode.

Lenarz (2013) reported results of a prospective multi-center European study evaluating the Nucleus Hybrid™ L24 system.^[110] The study enrolled 66 adults with bilateral severe-to-profound high frequency hearing loss. At one year post-operatively, 65% of subjects had significant gains in speech recognition in quiet and 73% had significant gains in noisy environments. Compared with the cochlear implant hearing alone, residual hearing significantly increased speech recognition scores.

Gifford (2013) compared hearing outcomes pre- and post-implantation for 44 adult cochlear implant recipients with preserved low-frequency hearing in two test conditions: cochlear implant plus low-frequency hearing in the contralateral ear (bimodal condition) and cochlear implant plus low-frequency hearing in both ears (best-aided condition).^[111] The authors reported that there were small but statistically significant differences in improvements in adaptive sentence recognition and speech recognition in a noisy “restaurant” environment, suggesting that the presence of residual hearing is beneficial.

A small number of studies in a small number of patients suggest that a hybrid cochlear implant system is associated with improvements in hearing of speech in quiet and noise. However, there are currently no available studies that compare the use of a standard hearing aid with a hybrid cochlear implant, which would be an appropriate comparison to determine if a hybrid device improves outcomes for patients who currently have hearing loss, but might not be candidate for a cochlear implant. In addition, there is only limited data to suggest that the preservation of residual hearing associated with a hybrid device is associated with improved outcomes compared with a standard cochlear implant.

Section Summary

Prospective and retrospective studies using a single-arm, within-subjects comparison pre- and postintervention have suggested that a hybrid cochlear implant system is associated with improvements in hearing of speech in quiet and noise. For patients who have high-frequency hearing loss but preserved low-frequency hearing, the available evidence has suggested that a hybrid cochlear implant improves speech recognition better than a hearing aid alone. Some studies have suggested that a shorter cochlear implant insertion depth may be associated with preserved residual low-frequency hearing, although there is uncertainty about the potential need for reoperation following hybrid cochlear implantation if there is a loss of residual hearing. Studies reporting on long-term outcomes and results of re-implantation are lacking.

PRACTICE GUIDELINE SUMMARY

AMERICAN ACADEMY OF OTOLARYNGOLOGY- HEAD AND NECK SURGERY

In 2020, the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) published a revised position statement on cochlear implants. The Academy “considers

unilateral and bilateral cochlear implantation as appropriate treatment for adults and children over 9 months of age with severe to profound hearing loss who have failed a trial with appropriately fit hearing aids.”^[112]

In 2020, the AAO-HNS published a position statement on pediatric cochlear implants.^[113] The Academy states that “there is ample evidence that early cochlear implantation of children with sensorineural hearing loss (SNHL) for whom hearing aids provide inadequate access to sound is advantageous.” The statement goes on to say that “Children with bilateral severe to profound SNHL (4-frequency PTA > 80 dB HL or 2-frequency PTA > 85) will not receive adequate benefit from amplification and are candidates for bilateral cochlear implantation. Children with this degree of SNHL, including infants between 6 and 12 months, should receive cochlear implants as soon as practicable.”

AMERICAN ACADEMY OF AUDIOLOGY

In July 2019, the American Academy of Audiology published clinical practice guidelines on cochlear implants.^[114] These guidelines include recommendations regarding cochlear implant evaluation. They recommend determining unaided air conduction and bone conduction thresholds using developmentally appropriate assessment measures. They additionally recommend determining auditory speech perception using appropriately fit amplification using developmentally appropriate assessment measures. Other recommendations are included regarding non-audiologic evaluation prior to implantation, and surgical and post-surgical roles for the audiologist.

AMERICAN COCHLEAR IMPLANT ALLIANCE TASK FORCE

In 2022 the American Cochlear Implant Alliance Task Force published two guidelines for clinical assessment and management of cochlear implantation for SSD. One for adults ^[115] and a separate guideline for children.^[116] The guidelines for adults with SSD has 16 recommendations for preoperative evaluation and post-activation assessment and management of adults with SSD, including:

1. It is recommended that individuals with sudden and/or rapid progression of SSD undergo standard medical workup and monitoring to determine if the hearing spontaneously improves or is recoverable with treatment, and that cochlear implantation should not occur earlier than 3 to 6 months after the sudden hearing loss to allow ample time for potential recovery of hearing. The potential exception to this is cases exhibiting evidence of progressive ossification (e.g., meningitis, after vestibular schwannoma resection, otic capsule fracture) where early implantation may be advantageous.
2. Consideration of the potential for significant bilateral hearing loss is warranted, as well as the benefits of early implantation of the impaired hearing ear for long-term performance benefit.

The guidelines for children with SSD include 13 recommendations for preoperative evaluation and post-activation assessment and management of adults with SSD, including: 1. Cochlear implantation to address SSD in an ear with cochlear nerve deficiency is contraindicated. Accurate diagnosis of nerve deficiency is important because it is present in almost half of children with SSD. Therefore, high resolution 3D MRI of the internal auditory canals is recommended rather than computer tomography alone.

2. Cochlear implantation should be considered a priority for children at risk of hearing loss progression in the better hearing ear. Children with SSD due to bacterial meningitis should be implanted promptly.
3. Younger age at implantation is expected to be advantageous in children with SSD. Children with longer lengths of deafness may experience fewer benefits and should be counseled as such. The impact of age and length of deafness is not yet fully understood in this population.
- 4.A CI evaluation is recommended for children with a unilateral three frequency pure tone average (3FPTA) of >60 dB HL and/or an aided SII < 0.65 because these children are unlikely to receive adequate benefit from traditional amplification.

SUMMARY

There is enough research to show that cochlear implants improve health outcomes, specifically, speech reception (especially in noise) and sound localization, for some patients who have severe to profound bilateral sensorineural hearing loss. Therefore, cochlear implants may be considered medically necessary in specific patients with bilateral hearing loss who meet the policy criteria.

The current research on cochlear implantation in patients diagnosed with enlarged vestibular aqueducts (EVA) has limitations. Despite these limitations, there is enough research to show that cochlear implants improve health outcomes, specifically, speech recognition, for patients with EVA. In addition, early placement of cochlear implants avoids atrophy and preserves hearing patients with EVA with moderate hearing loss. Therefore, cochlear implants may be considered medically necessary in patients with EVA when policy criteria are met.

The current research on hybrid cochlear implant/hearing aid systems has limitations. Despite these limitations, there is enough research to show that hybrid cochlear implant/hearing aid systems improve health outcomes, specifically, speech recognition, for patients aged 18 years or older who have high frequency sensorineural hearing loss with preserved low frequency hearing. Therefore, hybrid cochlear implant/hearing aid systems may be considered medically necessary in specific patients with high frequency sensorineural hearing loss with preserved low frequency hearing who meet the policy criteria.

There are currently no cochlear implants that have approval from the U.S. Food and Drug Administration (FDA) for use in patients who are younger than 9 months of age. There is not enough research to show that cochlear implants improve health outcomes in patients younger than 9 months of age and it is unclear that the benefits of early cochlear implantation outweigh the risk of surgery and anesthesia in these very young patients. In addition, there are no clinical practice guidelines from U.S. professional societies that recommend cochlear implantation in these very young patients. Therefore, cochlear implantation in patients younger than 9 months of age is considered not medically necessary.

The current research on cochlear implantation in patients diagnosed with unilateral hearing loss (UHL) including single sided deafness (SSD) or Asymmetric Hearing Loss (AHL) has limitations. Despite these limitations, there is enough research to show that cochlear implants improve health outcomes for patients with UHL. Therefore, cochlear implants may

be considered medically necessary in patients with UHL when policy criteria are met.

Bilateral or unilateral cochlear implants and hybrid cochlear implant/hearing aid systems do not improve health outcomes in all people with hearing loss, bilateral or single sided.

Therefore, cochlear implants and hybrid cochlear implant/hearing aid systems, bilateral or unilateral, are considered not medically necessary when the policy criteria are not met.

Implant replacement, including replacement parts or upgrades to existing cochlear implants and/or components may be considered medically necessary only in those patients whose response to the existing device is inadequate to the point of interfering with activities of daily living, including school or work. Replacement of an existing cochlear implant device is considered not medically necessary when the policy criteria are not met.

REFERENCES

1. U.S. Food and Drug Administration (FDA). Approval Letter: Nucleus Hybrid L24 Cochlear Implant System --P130016. 2014. [cited 3/8/2023]. 'Available from:' http://www.accessdata.fda.gov/cdrh_docs/pdf13/P130016a.pdf.
2. U.S. Food and Drug Administration (FDA). Approval Letter: Nucleus Hybrid L24 Cochlear Implant System - P970051/S205. 2022. [cited 3/9/2023]. 'Available from:' https://www.accessdata.fda.gov/cdrh_docs/pdf/P970051S205A.pdf.
3. Food and Drug Administration (FDA) premarket approval application (PMA) letter for the MED-EL EAS. [cited 3/8/2023]. 'Available from:' http://www.accessdata.fda.gov/cdrh_docs/pdf/p000025s084a.pdf.
4. FDA Summary of Safety and Effectiveness Data for Med-EL EAS System. [cited 3/8/2023]. 'Available from:' http://www.accessdata.fda.gov/cdrh_docs/pdf/p000025s084b.pdf.
5. U.S. Food and Drug Administration (FDA). Approval Letter: MED-EL Cochlear - P000025/S104. 2019. [cited 3/9/2023]. 'Available from:' www.accessdata.fda.gov/cdrh_docs/pdf/P000025S104A.pdf.
6. 1995 NIH Consensus Conference: Cochlear Implants in Adults and Children. NIH Consensus Statement Online 1995 May 15-17;13(2):1-30. [cited 3/8/2023]. 'Available from:' <http://consensus.nih.gov/1995/1995CochlearImplants100html.htm>.
7. (NIDCD) NNloDaoCD. Enlarged Vestibular Aqueducts and Childhood Hearing Loss. [cited 3/8/2023]. 'Available from:' <https://www.nidcd.nih.gov/health/enlarged-vestibular-aqueducts-and-childhood-hearing-loss>.
8. Alahmadi A, Abdelsamad Y, Salamah M, et al. Cochlear implantation in adults and pediatrics with enlarged vestibular aqueduct: a systematic review on the surgical findings and patients' performance. *Eur Arch Otorhinolaryngol*. 2022;279(12):5497-509. PMID: 35771280
9. Pan L, Lin H, Li X, et al. Systematic review and meta-analysis of cochlear implantation in deaf patients with large vestibular aqueduct deformity. *Ann Palliat Med*. 2021;10(12):12598-606. PMID: 35016448
10. Xu Q, Zhai S, Han D, et al. [Meta-analysis of the efficacy of cochlear implantation in deaf patients with inner ear malformation]. *Lin chuang er bi yan hou tou jing wai ke za zhi = Journal of clinical otorhinolaryngology, head, and neck surgery*. 2014;29(8):743-7. PMID: 26248452

11. Pakdaman MN, Herrmann BS, Curtin HD, et al. Cochlear implantation in children with anomalous cochleovestibular anatomy: a systematic review. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery*. 2012;146:180-90. PMID: 22140206
12. Vassoler TM, Bergonse Gda F, Meira Junior S, et al. Cochlear implant and large vestibular aqueduct syndrome in children. *Brazilian journal of otorhinolaryngology*. 2008;74(2):260-4. PMID: 18568206
13. Temple RH, Ramsden RT, Axon PR, et al. The large vestibular aqueduct syndrome: the role of cochlear implantation in its management. *Clinical otolaryngology and allied sciences*. 1999;24(4):301-6. PMID: 10472464
14. Pritchett C, Zwolan T, Huq F, et al. Variations in the cochlear implant experience in children with enlarged vestibular aqueduct. *The Laryngoscope*. 2015;125(9):2169-74. PMID: 25647353
15. Powell HR, Birman CS. Large vestibular aqueduct syndrome: Impedance changes over time with different cochlear implant electrode arrays. *Cochlear Implants Int*. 2015;16(6):326-30. PMID: 26098963
16. Loundon N, Rouillon I, Munier N, et al. Cochlear implantation in children with internal ear malformations. *Otol Neurotol*. 2005;26:668-73. PMID: 16015165
17. Lee KH, Lee J, Isaacson B, et al. Cochlear implantation in children with enlarged vestibular aqueduct. *The Laryngoscope*. 2010;120(8):1675-81. PMID: 20641086
18. Fahy CP, Carney AS, Nikolopoulos TP, et al. Cochlear implantation in children with large vestibular aqueduct syndrome and a review of the syndrome. *Int J Pediatr Otorhinolaryngol*. 2001;59:207-15. PMID: 11397503
19. Buchman CA, Copeland BJ, Yu KK, et al. Cochlear implantation in children with congenital inner ear malformations. *The Laryngoscope*. 2004;114(2):309-16. PMID: 14755210
20. Manzoor NF, Wick CC, Wahba M, et al. Bilateral Sequential Cochlear Implantation in Patients With Enlarged Vestibular Aqueduct (EVA) Syndrome. *Otol Neurotol*. 2016;37:e96-103. PMID: 26756161
21. Harker LA, Vanderheiden S, Veazey D, et al. Multichannel cochlear implantation in children with large vestibular aqueduct syndrome. *The Annals of otology, rhinology & laryngology Supplement*. 1999;177:39-43. PMID: 10214800
22. Bent JP, 3rd, Chute P, Parisier SC. Cochlear implantation in children with enlarged vestibular aqueducts. *The Laryngoscope*. 1999;109(7 Pt 1):1019-22. PMID: 10401833
23. Ko HC, Liu TC, Lee LA, et al. Timing of surgical intervention with cochlear implant in patients with large vestibular aqueduct syndrome. *PLoS One*. 2013;8:e81568. PMID: 24282608
24. Au G, Gibson W. Cochlear implantation in children with large vestibular aqueduct syndrome. *The American journal of otology*. 1999;20(2):183-6. PMID: 10100520
25. Bichey BG, Hoversland JM, Wynne MK, et al. Changes in quality of life and the cost-utility associated with cochlear implantation in patients with large vestibular aqueduct syndrome. *Otol Neurotol*. 2002;23(3):323-7. PMID: 11981389
26. Sbeih F, Bouzaher MH, Appachi S, et al. Safety of Cochlear Implantation in Children 12 Months or Younger: Systematic Review and Meta-analysis. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery*. 2022:1945998211067741. PMID: 34982600
27. Forli F, Arslan E, Bellelli S, et al. Systematic review of the literature on the clinical effectiveness of the cochlear implant procedure in paediatric patients. *Acta*

- otorhinolaryngologica Italica : organo ufficiale della Societa italiana di otorinolaringologia e chirurgia cervico-facciale*. 2011;31(5):281-98. PMID: 22287820
28. Vlastarakos PV, Proikas K, Papacharalampous G, et al. Cochlear implantation under the first year of age--the outcomes. A critical systematic review and meta-analysis. *Int J Pediatr Otorhinolaryngol*. 2010;74(2):119-26. PMID: 19896223
 29. Food and Drug Administration. Summary of Safety and Effectiveness Data. Cochlear Americas Nucleus 24 Cochlear Implant System (P970051/S172). 2020. [cited 3/8/2023]. 'Available from:' https://www.accessdata.fda.gov/cdrh_docs/pdf/P970051S172B.pdf.
 30. Kalejaiye A, Ansari G, Ortega G, et al. Low surgical complication rates in cochlear implantation for young children less than 1 year of age. *The Laryngoscope*. 2017;127(3):720-24. PMID: 27411677
 31. Guerzoni L, Murri A, Fabrizi E, et al. Social conversational skills development in early implanted children. *The Laryngoscope*. 2016;126(9):2098-105. PMID: 26649815
 32. Colletti L, Mandala M, Zoccante L, et al. Infants versus older children fitted with cochlear implants: performance over 10 years. *Int J Pediatr Otorhinolaryngol*. 2011;75(4):504-9. PMID: 21277638
 33. Colletti L. Long-term follow-up of infants (4-11 months) fitted with cochlear implants. *Acta Otolaryngol*. 2009;129(4):361-6. PMID: 19153846
 34. Ching TY, Dillon H, Day J, et al. Early language outcomes of children with cochlear implants: interim findings of the NAL study on longitudinal outcomes of children with hearing impairment. *Cochlear Implants Int*. 2009;10 Suppl 1:28-32. PMID: 19067433
 35. Johr M, Ho A, Wagner CS, et al. Ear surgery in infants under one year of age: its risks and implications for cochlear implant surgery. *Otol Neurotol*. 2008;29(3):310-3. PMID: 18364573
 36. Bilateral Cochlear Implantation: A Health Technology Assessment. *Ontario health technology assessment series*. 2018;18(6):1-139. PMID: 30443278
 37. McRackan TR, Bauschard M, Hatch JL, et al. Meta-analysis of quality-of-life improvement after cochlear implantation and associations with speech recognition abilities. *The Laryngoscope*. 2018;128(4):982-90. PMID: 28731538
 38. McRackan TR, Bauschard M, Hatch JL, et al. Meta-analysis of Cochlear Implantation Outcomes Evaluated With General Health-related Patient-reported Outcome Measures. *Otol Neurotol*. 2018;39(1):29-36. PMID: 29227446
 39. Gaylor JM, Raman G, Chung M, et al. Cochlear implantation in adults: a systematic review and meta-analysis. *JAMA otolaryngology-- head & neck surgery*. 2013;139(3):265-72. PMID: 23429927
 40. Berrettini S, Baggiani A, Bruschini L, et al. Systematic review of the literature on the clinical effectiveness of the cochlear implant procedure in adult patients. *Acta otorhinolaryngologica Italica : organo ufficiale della Societa italiana di otorinolaringologia e chirurgia cervico-facciale*. 2011;31(5):299-310. PMID: 22287821
 41. Raman G LJ, Chung M., et al. . Effectiveness of Cochlear Implants in Adults with Sensorineural Hearing Loss. AHRQ Technology Assessment Report. June 17, 2011. [cited 3/8/2023]. 'Available from:' <http://www.cms.gov/determinationprocess/downloads/id80TA.pdf>.
 42. Fernandes NF, Morettin M, Yamaguti EH, et al. Performance of hearing skills in children with auditory neuropathy spectrum disorder using cochlear implant: a systematic review. *Brazilian journal of otorhinolaryngology*. 2015;81(1):85-96. PMID: 25458263

43. Lammers MJ, van der Heijden GJ, Pourier VE, et al. Bilateral cochlear implantation in children: a systematic review and best-evidence synthesis. *The Laryngoscope*. 2014;124(7):1694-9. PMID: 24390811
44. Eze N, Ofo E, Jiang D, et al. Systematic review of cochlear implantation in children with developmental disability. *Otol Neurotol*. 2013;34(8):1385-93. PMID: 24005167
45. Humphriss R, Hall A, Maddocks J, et al. Does cochlear implantation improve speech recognition in children with auditory neuropathy spectrum disorder? A systematic review. *International journal of audiology*. 2013;52(7):442-54. PMID: 23705807
46. Smulders YE, van Zon A, Stegeman I, et al. Comparison of Bilateral and Unilateral Cochlear Implantation in Adults: A Randomized Clinical Trial. *JAMA otolaryngology-- head & neck surgery*. 2016;142:249-56. PMID: 26796630
47. van Zon A, Smulders YE, Stegeman I, et al. Stable benefits of bilateral over unilateral cochlear implantation after two years: A randomized controlled trial. *The Laryngoscope*. 2017;127(5):1161-68. PMID: 27667732
48. Ching TY, Incerti P, Hill M. Binaural benefits for adults who use hearing aids and cochlear implants in opposite ears. *Ear Hear*. 2004;25(1):9-21. PMID: 14770014
49. Ching TY, Incerti P, Hill M, et al. An overview of binaural advantages for children and adults who use binaural/bimodal hearing devices. *Audiol Neurotol*. 2006;11 Suppl 1:6-11. PMID: 17063004
50. Holt RF, Kirk KI, Eisenberg LS, et al. Spoken word recognition development in children with residual hearing using cochlear implants and hearing AIDS in opposite ears. *Ear Hear*. 2005;26(4 Suppl):82S-91S. PMID: 16082270
51. Litovsky RY, Johnstone PM, Godar S, et al. Bilateral cochlear implants in children: localization acuity measured with minimum audible angle. *Ear Hear*. 2006;27(1):43-59. PMID: 16446564
52. Litovsky R, Parkinson A, Arcaroli J, et al. Simultaneous bilateral cochlear implantation in adults: a multicenter clinical study. *Ear Hear*. 2006;27(6):714-31. PMID: 17086081
53. Ricketts TA, Grantham DW, Ashmead DH, et al. Speech recognition for unilateral and bilateral cochlear implant modes in the presence of uncorrelated noise sources. *Ear Hear*. 2006;27(6):763-73. PMID: 17086085
54. Ramsden R, Greenham P, O'Driscoll M, et al. Evaluation of bilaterally implanted adult subjects with the nucleus 24 cochlear implant system. *Otol Neurotol*. 2005;26(5):988-98. PMID: 16151348
55. Kuhn-Inacker H, Shehata-Dieler W, Muller J, et al. Bilateral cochlear implants: a way to optimize auditory perception abilities in deaf children? *Int J Pediatr Otorhinolaryngol*. 2004;68(10):1257-66. PMID: 15364496
56. Blamey PJ, Maat B, Baskent D, et al. A Retrospective Multicenter Study Comparing Speech Perception Outcomes for Bilateral Implantation and Bimodal Rehabilitation. *Ear Hear*. 2015;36(4):408-16. PMID: 25695925
57. Choi JS, Betz J, Li L, et al. Association of Using Hearing Aids or Cochlear Implants With Changes in Depressive Symptoms in Older Adults. *JAMA otolaryngology-- head & neck surgery*. 2016;142(7):652-7. PMID: 27258813
58. Escorihuela Garcia V, Pitarch Ribas MI, Llopez Carratala I, et al. Comparative study between unilateral and bilateral cochlear implantation in children of 1 and 2 years of age. *Acta otorrinolaringologica espanola*. 2016;67(3):148-55. PMID: 26632253
59. Killan CF, Royle N, Totten CL, et al. The effect of early auditory experience on the spatial listening skills of children with bilateral cochlear implants. *Int J Pediatr Otorhinolaryngol*. 2015;79(12):2159-65. PMID: 26520909

60. Friedmann DR, Green J, Fang Y, et al. Sequential bilateral cochlear implantation in the adolescent population. *The Laryngoscope*. 2015;125(8):1952-8. PMID: 25946482
61. Sarant J, Harris D, Bennet L, et al. Bilateral versus unilateral cochlear implants in children: a study of spoken language outcomes. *Ear Hear*. 2014;35(4):396-409. PMID: 24557003
62. Kontorinis G, Lloyd SK, Henderson L, et al. Cochlear implantation in children with auditory neuropathy spectrum disorders. *Cochlear Implants Int*. 2014;15 Suppl 1:S51-4. PMID: 24869444
63. Broomfield SJ, Murphy J, Emmett S, et al. Results of a prospective surgical audit of bilateral paediatric cochlear implantation in the UK. *Cochlear Implants Int*. 2013;14 Suppl 4:S19-21. PMID: 24533758
64. Illg A, Giourgas A, Kral A, et al. Speech comprehension in children and adolescents after sequential bilateral cochlear implantation with long interimplant interval. *Otol Neurotol*. 2013;34(4):682-9. PMID: 23640090
65. Sharma A, Dorman MF. Central auditory development in children with cochlear implants: clinical implications. *Adv Otorhinolaryngol*. 2006;64:66-88. PMID: 16891837
66. Sharma A, Dorman MF, Kral A. The influence of a sensitive period on central auditory development in children with unilateral and bilateral cochlear implants. *Hear Res*. 2005;203(1-2):134-43. PMID: 15855038
67. Baron S, Blanchard M, Parodi M, et al. Sequential bilateral cochlear implants in children and adolescents: Outcomes and prognostic factors. *European annals of otorhinolaryngology, head and neck diseases*. 2019;136(2):69-73. PMID: 30314876
68. Idriss SA, Reynard P, Marx M, et al. Short- and Long-Term Effect of Cochlear Implantation on Disabling Tinnitus in Single-Sided Deafness Patients: A Systematic Review. *J Clin Med*. 2022;11(19). PMID: 36233532
69. Oh SJ, Mavrommatis MA, Fan CJ, et al. Cochlear Implantation in Adults With Single-Sided Deafness: A Systematic Review and Meta-analysis. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery*. 2022:1945998221083283. PMID: 35230924
70. Donato M, Santos R, Correia F, et al. Single-sided deafness: Bone conduction devices or cochlear implantation? A systematic review with meta-analysis. *Acta Otorrinolaringol Esp (Engl Ed)*. 2021;72(2):101-08. PMID: 33160618
71. Assouly KKS, van Heteren JAA, Stokroos RJ, et al. Cochlear implantation for patients with tinnitus - A systematic review. *Prog Brain Res*. 2021;260:27-50. PMID: 33637223
72. Benchetrit L, Ronner EA, Anne S, et al. Cochlear Implantation in Children With Single-Sided Deafness: A Systematic Review and Meta-analysis. *JAMA otolaryngology-- head & neck surgery*. 2021;147(1):58-69. PMID: 33151295
73. Implantable Devices for Single-Sided Deafness and Conductive or Mixed Hearing Loss: A Health Technology Assessment. *Ontario health technology assessment series*. 2020;20(1):1-165. PMID: 32194878
74. Levy DA, Lee JA, Nguyen SA, et al. Cochlear Implantation for Treatment of Tinnitus in Single-sided Deafness: A Systematic Review and Meta-analysis. *Otol Neurotol*. 2020;41(8):e1004-e12. PMID: 32558752
75. Peter N, Liyanage N, Pfiffner F, et al. The Influence of Cochlear Implantation on Tinnitus in Patients with Single-Sided Deafness: A Systematic Review. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery*. 2019;161(4):576-88. PMID: 31060475

76. Cabral Junior F, Pinna MH, Alves RD, et al. Cochlear Implantation and Single-sided Deafness: A Systematic Review of the Literature. *Int Arch Otorhinolaryngol.* 2016;20(1):69-75. PMID: 26722349
77. Peters JP, Ramakers GG, Smit AL, et al. Cochlear implantation in children with unilateral hearing loss: A systematic review. *The Laryngoscope.* 2016;126(3):713-21. PMID: 26343240
78. van Zon A, Peters JP, Stegeman I, et al. Cochlear implantation for patients with single-sided deafness or asymmetrical hearing loss: a systematic review of the evidence. *Otol Neurotol.* 2015;36(2):209-19. PMID: 25502451
79. Vlastarakos PV, Nazos K, Tavoulari EF, et al. Cochlear implantation for single-sided deafness: the outcomes. An evidence-based approach. *Eur Arch Otorhinolaryngol.* 2014;271(8):2119-26. PMID: 24096818
80. Blasco MA, Redleaf MI. Cochlear implantation in unilateral sudden deafness improves tinnitus and speech comprehension: meta-analysis and systematic review. *Otol Neurotol.* 2014;35(8):1426-32. PMID: 24786540
81. Marx M, Mosnier I, Venail F, et al. Cochlear Implantation and Other Treatments in Single-Sided Deafness and Asymmetric Hearing Loss: Results of a National Multicenter Study Including a Randomized Controlled Trial. *Audiol Neurootol.* 2021;26(6):414-24. PMID: 33789270
82. Peters JPM, van Heteren JAA, Wendrich AW, et al. Short-term outcomes of cochlear implantation for single-sided deafness compared to bone conduction devices and contralateral routing of sound hearing aids-Results of a Randomised controlled trial (CINGLE-trial). *PLoS One.* 2021;16(10):e0257447. PMID: 34644322
83. Arras T, Boudewyns A, Swinnen F, et al. Longitudinal auditory data of children with prelingual single-sided deafness managed with early cochlear implantation. *Sci Rep.* 2022;12(1):9376. PMID: 35672363
84. Brown KD, Dillon MT, Park LR. Benefits of Cochlear Implantation in Childhood Unilateral Hearing Loss (CUHL Trial). *The Laryngoscope.* 2022;132 Suppl 6(Suppl 6):S1-s18. PMID: 34542181
85. Administration USFaD. Summary of Safety and Effectiveness Data: Nucleus Cochlear Implant System: PMA970051/s205B 2022. [cited 04/06/2023]. 'Available from:' www.accessdata.fda.gov/cdrh_docs/pdf/P970051S205B.pdf.
86. Falcón Benítez N, Falcón González JC, Ramos Macías Á, et al. Cochlear Implants in Single-Sided Deafness. Comparison Between Children and Adult Populations With Post-lingually Acquired Severe to Profound Hearing Loss. *Front Neurol.* 2021;12:760831. PMID: 34803893
87. Rauch AK, Arndt S, Aschendorff A, et al. Long-term results of cochlear implantation in children with congenital single-sided deafness. *Eur Arch Otorhinolaryngol.* 2021;278(9):3245-55. PMID: 33079248
88. Poncet-Wallet C, Mamelle E, Godey B, et al. Prospective Multicentric Follow-up Study of Cochlear Implantation in Adults With Single-Sided Deafness: Tinnitus and Audiological Outcomes. *Otol Neurotol.* 2020;41(4):458-66. PMID: 32176124
89. Dillon MT, Buss E, Rooth MA, et al. Cochlear Implantation in Cases of Asymmetric Hearing Loss: Subjective Benefit, Word Recognition, and Spatial Hearing. *Trends in hearing.* 2020;24:2331216520945524. PMID: 32808881
90. Buss E, Dillon MT, Rooth MA, et al. Effects of Cochlear Implantation on Binaural Hearing in Adults With Unilateral Hearing Loss. *Trends in hearing.* 2018;22:2331216518771173. PMID: 29732951

91. Dillon MT, Buss E, O'Connell BP, et al. Low-Frequency Hearing Preservation With Long Electrode Arrays: Inclusion of Unaided Hearing Threshold Assessment in the Postoperative Test Battery. *American journal of audiology*. 2020;29(1):1-5. PMID: 31835906
92. Galvin JJ, 3rd, Fu QJ, Wilkinson EP, et al. Benefits of Cochlear Implantation for Single-Sided Deafness: Data From the House Clinic-University of Southern California-University of California, Los Angeles Clinical Trial. *Ear Hear*. 2019;40(4):766-81. PMID: 30358655
93. Peter N, Kleinjung T, Probst R, et al. Cochlear implants in single-sided deafness - clinical results of a Swiss multicentre study. *Swiss medical weekly*. 2019;149:w20171. PMID: 31880806
94. Food and Drug Administration. Summary of Safety and Effectiveness Data (SSED): MED-EL Cochlear Implant System (P000025/S104). 2019. [cited 3/4/2023]. 'Available from:' https://www.accessdata.fda.gov/cdrh_docs/pdf/P000025S104B.pdf.
95. Food and Drug Administration. Post-Approval Studies (PAS): MED-EL New Enrollment SSD/AHL Study. 2020. [cited 3/8/2023]. 'Available from:' https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma_pas.cfm?t_id=647845&c_id=5585.
96. Arndt S, Laszig R, Aschendorff A, et al. Cochlear implant treatment of patients with single-sided deafness or asymmetric hearing loss. *Hno*. 2017;65(Suppl 2):98-108. PMID: 28188428
97. Sladen DP, Frisch CD, Carlson ML, et al. Cochlear implantation for single-sided deafness: A multicenter study. *The Laryngoscope*. 2017;127(1):223-28. PMID: 27346874
98. Rahne T, Plontke SK. Functional Result After Cochlear Implantation in Children and Adults With Single-sided Deafness. *Otol Neurotol*. 2016;37(9):e332-40. PMID: 27631656
99. Mertens G, De Bodt M, Van de Heyning P. Cochlear implantation as a long-term treatment for ipsilateral incapacitating tinnitus in subjects with unilateral hearing loss up to 10 years. *Hear Res*. 2016;331:1-6. PMID: 26433053
100. Ramos Macias A, Falcon Gonzalez JC, Manrique M, et al. Cochlear implants as a treatment option for unilateral hearing loss, severe tinnitus and hyperacusis. *Audiol Neurootol*. 2015;20 Suppl 1:60-6. PMID: 25997672
101. Arndt S, Prosse S, Laszig R, et al. Cochlear implantation in children with single-sided deafness: does aetiology and duration of deafness matter? *Audiol Neurootol*. 2015;20 Suppl 1:21-30. PMID: 25999052
102. Hansen MR, Gantz BJ, Dunn C. Outcomes after cochlear implantation for patients with single-sided deafness, including those with recalcitrant Meniere's disease. *Otol Neurotol*. 2013;34:1681-7. PMID: 24232066
103. Tavora-Vieira D, Marino R, Krishnaswamy J, et al. Cochlear implantation for unilateral deafness with and without tinnitus: a case series. *The Laryngoscope*. 2013;123(5):1251-5. PMID: 23553411
104. Santa Maria PL, Gluth MB, Yuan Y, et al. Hearing preservation surgery for cochlear implantation: a meta-analysis. *Otol Neurotol*. 2014;35(10):e256-69. PMID: 25233333
105. Pillsbury HC, 3rd, Dillon MT, Buchman CA, et al. Multicenter US Clinical Trial With an Electric-Acoustic Stimulation (EAS) System in Adults: Final Outcomes. *Otol Neurotol*. 2018;39(3):299-305. PMID: 29342054

L8618	Transmitter cable for use with cochlear implant device or auditory osseointegrated device, replacement
L8619	Cochlear implant external speech processor and controller, integrated system, replacement
L8621	Zinc air battery for use with cochlear implant device and auditory osseointegrated sound processors, replacement, each
L8622	Alkaline battery for use with cochlear implant device, any size, replacement, each
L8623	Lithium ion battery for use with cochlear implant device speech processor
L8624	Lithium ion battery for use with cochlear implant or auditory osseointegrated device speech processor, ear level, replacement, each
L8625	External recharging system for battery for use with cochlear implant or auditory osseointegrated device, replacement only, each
L8627	Cochlear implant, external speech processor, component, replacement
L8628	Cochlear implant, external controller component, replacement
L8629	Transmitting coil and cable, integrated, for use with cochlear implant device, replacement

Date of Origin: January 1996