

Hearing aid or cochlear implant? A reasoned approach to determining cochlear implant candidacy

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Abstract

The cochlear implant (CI) was approved as a treatment for profound hearing loss in 1985 in the United States and in 1995 in Spain. Since then, CI candidacy criteria have evolved alongside scientific and technological advances. Currently, individuals with bilateral severe hearing loss (≥ 70 dB HL) are CI candidates in most countries. The aim of this study was to investigate whether 'borderline' patients, i.e., those who do not reach severe hearing loss, could show better performance with CIs than with hearing aids. The reviewed scientific evidence shows that patients with average audiometric thresholds (0.5–2 kHz) of 65 dB HL have an 80% likelihood of performing better with a CI than with one or two hearing aids. The evidence also shows that monosyllabic word recognition is more sensitive for establishing CI candidacy than sentence recognition. Individuals with preoperative word recognition scores below 60% in the best-aided condition perform better with a CI and a contralateral hearing aid than with bilateral hearing aids. Cochlear implantation reduces the emotional and social impact of hearing loss and increases the quality of life of individuals who receive the implant. Our findings align with recent literature suggesting that professionals should refer patients for CI candidacy evaluation when their average audiometric thresholds exceed 60–65 dB HL and word recognition scores are below 60% in the best-aided condition.

Keywords

Hearing loss, speech recognition, satisfaction, quality of life.

Clinical implications

Optimal management of hearing loss is crucial to minimize its negative impact on both individuals and society. A variety of auditory devices are available for the treatment of hearing loss, including hearing aids and cochlear implants (CIs). In this article, we examine current CI candidacy criteria in Spain and in other countries. We review the literature to assess whether hearing-aid users who do not meet the severe hearing loss criterion may achieve better outcomes with CIs than with hearing aids. The available evidence indicates that patients with moderate hearing loss (thresholds >60 – 65 dB HL) and word recognition scores below 60% in the best-aided condition are likely to derive greater functional benefit from CIs than from hearing aids.

Introduction

Hearing loss is the third most common disability in the world (British Deaf Association, 2015). More than 1.5 billion people (19% of the world’s population) experience some degree of hearing loss, and 430 million require treatment (WHO, 2025). Untreated hearing loss increases the risk of developing dementia by 8% (Livingston et al., 2024) and is associated with feelings of loneliness and social isolation (Shukla et al., 2020), two factors that increase mortality and the likelihood of cardiovascular disease (Leigh-Hunt et al., 2017; Livingston et al., 2024). As a result, one trillion dollars are lost worldwide each year due to inadequate or absent management of hearing loss (WHO, 2021). Optimal treatment of hearing loss is therefore essential to reduce its negative impact, both on patients and society.

Several devices are available for the treatment of hearing loss, including hearing aids and cochlear implants (CIs). In this article, we analyze current CI candidacy criteria in Spain and other countries. Since these criteria vary across countries and evolve alongside scientific and technological advancements, we have reviewed the specialized literature to address the following question: could some hearing aid users who do not meet the current implantation criteria perform better with CIs?

Indications and limitations of hearing aids

Hearing aids amplify sounds to compensate for the loss of auditory sensitivity and are the most common treatment for individuals with moderate sensorineural hearing loss (40–70 dB HL). Although these devices restore sound audibility, hearing-aid users usually experience more difficulty understanding speech than normal-hearing individuals (Alkaf & Firszt, 2007; Leigh et al., 2016; Lopez-Poveda et al., 2017; Peters et al., 1998). This can be observed in **Figure 1A**, which shows that the greater the hearing loss, the poorer the performance of hearing-aid users in a speech-recognition task. This difficulty is associated with both hearing aid limitations and degraded encoding of speech cues in the damaged auditory system.

On the one hand, as hearing loss increases, the range of sound levels that the listener can perceive decreases. Therefore, the hearing aid must amplify and, at the same time, compress the range of speech levels so that soft speech becomes audible but loud speech does not get uncomfortably loud. If the range of sound levels is compressed excessively, speech is more likely to be distorted, especially when the hearing aid is fast-acting, which may hinder speech recognition (e.g., Jorgensen et al., 2018). Speech may also be distorted because certain speech segments reach the maximum output level that the hearing aid can provide (Davies-Venn et al., 2009).

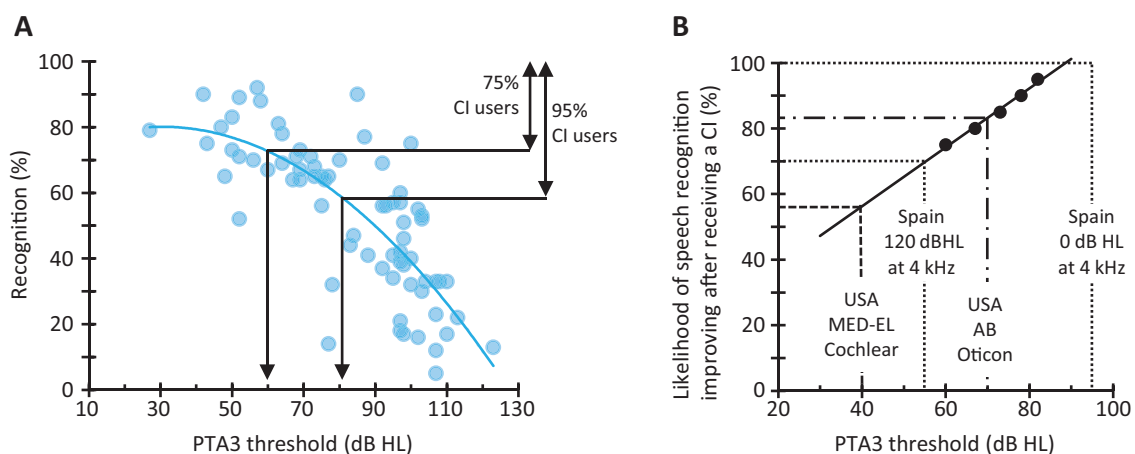


Figure 1. A. Phoneme recognition in quiet for hearing-aid users as a function of average audiometric threshold at 0.5, 1 and 2 kHz (PTA3 threshold) (N=76). Recognition was measured with one or two hearing aids. The PTA3 threshold was measured without amplification. Horizontal lines indicate that 75% and 95% of CI users achieve phoneme recognition $\geq 73\%$ and $\geq 58\%$, respectively. Based on the regression model (blue line), these values correspond to PTA3 thresholds of 60 and 82 dB HL in hearing-aid users (see the two leftmost arrows). Figure adapted from Leigh et al. (2016). B. Likelihood that speech recognition for hearing-aid users improves after they receive a CI as a function of the PTA3 threshold (measured without amplification). The dots correspond to the data inferred by Leigh et al. (2016) while the solid line illustrates a linear fit to the data. The dotted and dashed lines show the audiometric thresholds for an adult with bilateral hearing loss to be considered a CI candidate across countries and brands (Table 1). AB: Advanced Bionics.

On the other hand, greater hearing loss is associated with a higher likelihood of dysfunction or loss of inner hair cells and/or cochlear synapses, thus with an increased probability of cochlear dead regions. When dead regions are present, portions of the speech signal are not transmitted through the affected areas (Johannesen et al., 2014; Jorgensen et al., 2018). This can disrupt the temporal and spectral processing of speech, causing hearing-aid users to experience poorer speech recognition than would be expected based on audibility alone. Therefore, the person may hear the speech but find it difficult to understand it (Jorgensen et al., 2018; Souza et al., 2007; Summers et al., 2013).

Another limitation of hearing aids is that by amplifying sound frequencies that would otherwise be inaudible for the user, they can cause those frequencies to be encoded through tonotopic regions that do not correspond to their original frequencies. That is, the most amplified sound frequencies may be perceived outside their natural tonotopic region, hindering detection and discrimination of other less amplified sound frequencies. This limitation can also cause hearing-aid users to detect speech without being able to discriminate it, especially when speech is presented together with other sounds or in noisy environments (Lopez-Poveda et al., 2017).

Cochlear implants also have limitations (Carlyon & Goehring, 2021). For example, like hearing aids, CIs compress the range of speech sound levels into a much narrower range of electrical current levels (Lopez-Poveda et al., 2016, 2017, 2020). In addition, CIs process sounds with poor spectral resolution. This is due to the limited number of channels in the audio processor as well as to the number of electrodes that can be activated simultaneously (Zhang et al., 2025). However, CIs stimulate the auditory nerve directly. Therefore, in contrast to hearing aids, CIs can stimulate cochlear dead regions. Although electrical stimulation may spread to tonotopically distant auditory nerve fibers, resulting in poor spectral resolution, this limitation can be partially controlled by CI coding strategies.

For these reasons, it seems reasonable to ask: Could CIs be advantageous over hearing aids, particularly when the latter are no longer effective? More specifically: At what degree of hearing loss does a patient perform better with a CI than with one or two hearing aids?

Cochlear implant candidacy criteria

Cochlear implant candidates must meet several requirements. Some of them are inherent to the device's functionality and, therefore, common across countries. For example, candidates must have a fully developed cochlea and a functional auditory nerve and central auditory pathway. Other requirements, however, are related to the hearing loss of the patient and to their performance on speech-recognition tasks with their hearing aid(s). Unlike the former, the latter criteria vary across countries.

In 1985, the United States Food and Drug Administration (FDA) approved the use of CIs in adults with bilateral postlingual profound hearing loss (>90 dB HL). In Spain, the Health Technology Assessment Agency (*Instituto de Salud Carlos III*) approved CIs for the treatment of profound hearing loss in 1995. Since then, prescription criteria have evolved over time, resulting in an increasing number of people being CI candidates (reviewed by Park et al., 2021; Zwolan & Basura, 2021). However, there is no international consensus regarding these criteria.

Table 1 summarizes the current criteria for cochlear implantation in the United Kingdom, Spain, and the United States. Focusing, for example, on adults with bilateral hearing loss, in the United Kingdom someone is a CI candidate if their thresholds exceed 80 dB HL at two or more frequencies between 0.5 and 4 kHz (NICE, 2019). In Spain, they must have thresholds >70 dB HL "in the range of conversational frequencies (from 0.5 to 4 kHz)" (Manrique et al., 2017), but it is not specified whether the criterion applies to each and every one of the frequencies or to the average across frequencies. In the United States, FDA indications differ across CI brands. For example, an adult with bilateral hearing loss may receive a MED-EL™ CI if they have a mean hearing threshold >40 dB HL at low frequencies (0.25, 0.5, and 1 kHz) and >65 dB HL at high frequencies (3–8 kHz) (FDA, 2024). However, their average threshold at 0.5, 1 and 2 kHz (called PTA3) must be ≥70 dB HL to receive an Oticon CI (Zwolan & Basura, 2021). It is unclear why the audiometric frequencies used to determine the hearing loss criterion vary across countries.

Regarding the speech-recognition performance criteria, Table 1 shows that the speech tests differ across countries and even across brands within the same country. In some cases, no specifications are given with respect to the type of speech material (sentences, words or syllables), the presentation sound

Table 1. Prescription criteria for cochlear implants in the United Kingdom, Spain, and the United States. The criteria for unilateral hearing loss also apply to asymmetric hearing loss. ¹Consonant-Nucleus-Consonant test (CNC, Peterson & Lehiste, 1962), ²Multisyllabic/Lexical Neighborhood Test (MLNT, Kirk et al., 1995), ³Hearing-In-Noise Test (HINT, Nilsson et al., 1994).

Country	Device	Age (years)	Hearing loss	Degree of hearing loss	Speech recognition with hearing aid(s)	
United Kingdom (NICE, 2019)	All CI brands, except for Neurelec (insufficient data available)	≥18	Unilateral or bilateral	≥80 dB HL in 2 or more frequencies (0.5, 1, 2, 3 and 4 kHz)	Phoneme recognition ≤50% in the Arthur Boothroyd word test presented at 70 dB A	
		<18				Speech, language, and oral comprehension skills not appropriate for age, developmental stage, and cognitive ability
Spain (Manrique et al., 2017)	All brands	≥18	Bilateral	>70 dB HL (0.5 to 4 kHz)	<40% in a speech test at 65 dB SPL	
		>6 months and <18 years	Unilateral	>70 dB HL in the CI ear	<50% in disyllable recognition in quiet at 65 dB SPL	
			Bilateral	>70 dB HL (0.5 to 4 kHz)	Minimal benefit with hearing aid. Language development and listening skills not correlated with age and cognition	
		<12	Unilateral	>70 dB HL		
		≥18	Bilateral	>40 dB HL (average 0.25, 0.5, 1 kHz) and >65 dB HL (average 3-8 kHz)	≤50% in the ear to be implanted and ≤60% in the non-implanted ear on the recorded CNC ¹ word test	
Bilateral	≥90 dB HL at 1 kHz		≤20% on the MLNT or LNT ² tests in the best-aided condition			
United States (FDA)	MED-EL	≥5	Unilateral	>90 dB HL	≤5% in the ear to be implanted on the CNC test	
		≥18	Bilateral	>40 dB HL at low frequencies and >90 dB HL at mid and high frequencies	<50% in the ear to be implanted and <60% in the best-aided condition for recorded sentences in open-set format	
	Cochlear	2-17	Bilateral	>70 dB HL	≤30% on the MLNT or LNT test in the best-aided condition	
		9 months-2 years	Bilateral	>90 dB HL	Limited benefit from binaural amplification	
	Advanced Bionics	≥5	Unilateral	>80 dB HL (average 0.5, 1, 2, 4 kHz)	≤5% on the CNC test in the ear to be implanted	
		≥18	Bilateral	>70 dB HL	≤50% in recognition of HINT ³ sentences in open-set format	
	Oticon	1-17	Bilateral	≥90 dB HL	≤20% on the MLNT or LNT test	
		≥18	Bilateral	≥70 dB HL (average 0.5, 1 and 2 kHz)	≤50% on HINT sentences in quiet or noise in the best-aided condition	

level, whether the measurement should be done in quiet or in noise, the type of noise, or the signal-to-noise ratio (SNR). It would be advisable to establish a universal criterion for the verbal material and assessment conditions.

Objectives of this work

The variability in implantation criteria across countries means that the same person might be considered a CI candidate in one country but not in another. Furthermore, eligibility can depend on the type of verbal test used to assess performance. For this reason, policymakers and healthcare professionals may find it difficult to determine whether they are truly providing the most effective treatment for patients. In this context, the primary aim of this study is to identify which patients would benefit more from a CI than from hearing aids.

On the other hand, CI criteria have evolved over time alongside advancements in CI technology (Hainarosie et al., 2014). For hearing aids, the benefit of technological advances is limited by damage to the patient's auditory system itself. Therefore, a second aim is to examine whether 'borderline' patients (who do not meet current implantation criteria) can show better performance with CIs than with hearing aids. Our hypothesis is that people who do not meet current implantation criteria can perform better and be more satisfied with a CI combined with a contralateral hearing aid than with bilateral hearing aids.

These aims will be achieved by analyzing data available in the scientific literature. The variables examined include the degree of hearing loss, performance in speech recognition tests, and the level of satisfaction after receiving a CI. Since the main objective is to provide a perspective on a topic relevant to the clinical field, the studies were selected based on their relevance and recency, without the intention of providing an exhaustive or systematic review of all available evidence.

Speech recognition with cochlear implants vs hearing aids

In this section, we review various scientific studies comparing the performance of CI users with hearing-aid users (between-group comparison). We also review studies that have evaluated individuals who did not

meet the criteria for CI candidacy based on their hearing loss and/or performance with hearing aids, but who nevertheless received a CI (within-group comparisons).

Between-group comparison

Numerous studies have examined speech recognition in quiet and in noise in hearing-aid users. Overall, these studies show that speech recognition declines as hearing loss increases, despite the hearing aid providing the prescribed amplification (Lopez-Poveda et al., 2017; Peters et al., 1998; Summers et al., 2013). This decline in recognition can be seen in Figure 1A, which shows phoneme recognition in quiet as a function of hearing loss for 62 participants (aged between 4.6 and 16.2 years) (Leigh et al., 2016). Hearing loss was calculated as the average audiometric threshold at 0.5, 1 and 2 kHz, hereafter referred to as PTA3. Speech recognition was measured using consonant-vowel-consonant (or CNC) words. Participants used hearing aids programmed with the NAL-RP or NAL-NL1 gain prescription rules (Byrne et al., 2001). Recognition was assessed bilaterally in participants with symmetrical hearing loss (N=48) and separately with each ear for participants with asymmetric hearing loss (N=14) (N=76 measures in total). Words were presented via live voice at 65 dB A or via a loudspeaker (recorded material) at 65 dB SPL. The audiologist or loudspeaker was in front of the participant. Given that phoneme recognition decreases as hearing loss increases (Figure 1A) and since CI users typically show high levels of speech recognition in quiet (e.g., $\geq 90\%$ in Dorman et al., 2000; Aamoodi et al., 2012), one can expect patients beyond a certain hearing loss to achieve better performance with a CI than with one or two hearing aids.

Leigh et al. (2016) investigated the hearing loss beyond which patients were more likely to perform better with a CI than with hearing aid(s). To do so, they compared the performance of hearing-aid users (Figure 1A) with the performance of CI users (N=78, 75 with unilateral CI and 3 bilateral) matched for ages and demographic characteristics. CI users had bilateral prelingual sensorineural hearing loss ($PTA3 \geq 83$ dB HL) and received the multichannel Nucleus® CI before 3 years of age. They used the most recent audio processor and sound processing strategy (ACE or SPEAK) and had 20 or more active electrodes. Leigh et al. (2016) observed that 75% of CI users showed phoneme recognition $\geq 73\%$ when they perceived speech through the CI ear. This score corresponded

to that shown by hearing-aid users with audiometric thresholds of 60 dB HL (Figure 1A). Thus, patients with unaided PTA3 thresholds ≥ 60 dB HL had 75% likelihood of performing better with a CI than with hearing aids, at least when speech is presented in quiet. Likewise, 95% of CI users showed word recognition $\geq 58\%$, which corresponds to the mean performance of hearing-aid users with PTA3 thresholds of 82 dB HL (Figure 1A). Therefore, patients with unaided PTA3 thresholds ≥ 82 dB HL have a 95% likelihood of performing better with a CI than with hearing aids.

To relate these probabilities to current CI candidacy criteria, Figure 1B shows the likelihood that individuals with bilateral hearing loss perform better with a single CI than with one or two hearing aids. The five points correspond to the two likelihood values described in the preceding paragraph plus three intermediate values. The line represents a linear fit to the five points, extrapolated to other PTA3 thresholds. As indicated in Table 1 and in Figure 1B, adults with bilateral hearing loss must have a mean threshold for low-frequency tones >40 dB HL to qualify for a MED-EL™ or a Cochlear® CI in the United States. According to Figure 1B, someone with a PTA3 threshold of 40 dB HL would have a 56% likelihood of performing better with a CI than with hearing aids, whereas an individual with a PTA3 threshold of 70 dB HL would have an 83% likelihood of performing better with a CI than with hearing aids.

Calculating the likelihood that Spanish individuals perform better with a CI than with hearing aid(s) is not straightforward because, as mentioned above, CI candidacy in Spain is based on audiometric thresholds at four frequencies (0.5, 1, 2 and 4 kHz) instead of three (0.5, 1 and 2 kHz or PTA3). Moreover, it is not specified whether the criterion refers to the average threshold across frequencies or to each and every one of them. However, approximations can be made. If the Spanish criterion referred to the average value across the four frequencies (PTA4) and considering that the criterion is to have a threshold ≥ 71 dB HL (Table 1), an individual with an audiometric threshold of 0 dB HL at 4 kHz would be eligible for a CI if their PTA3 threshold were >95 dB HL. In contrast, if their threshold at 4 kHz were 120 dB HL, the individual would qualify for a CI with a PTA3 >55 dB HL. According to Figure 1B, these PTA3 thresholds (55 and 95 dB HL) would correspond to probabilities of 70% and 100%, respectively, of showing better performance with a CI than with hearing aids. Thus, in

Spain, individuals are eligible to receive a CI when the likelihood that they perform better with a CI ranges from 70% to 100%. Therefore, the Spanish performance criterion is more restrictive than that of the United States.

It is difficult to define the threshold of improvement necessary to classify an individual as a CI candidate. Leigh et al. (2016) proposed that individuals with PTA3 ≥ 65 dB HL, who have an 80% likelihood of performing better with the CI, should be candidates. However, in the United States, for some brands a PTA3 ≥ 40 dB HL is sufficient (likelihood of better performance with a CI of 56%), when thresholds exceed 65 dB HL at higher frequencies (Table 1). The study by Leigh et al. (2016) is consistent with more recent research by Zwolan et al. (2020), who suggested that professionals should refer patients for CI candidacy evaluation when their PTA3 thresholds exceed 60–65 dB HL.

Within-group comparison: recognition before and after receiving a CI

This section reviews studies where individuals who did not meet CI candidacy nevertheless received one. It examines whether those individuals experienced improved speech recognition in quiet and in noise after receiving the implant.

Speech recognition in quiet

Gifford et al. (2010) measured sentence recognition (HINT or AzBio) and word recognition (CNC) in 22 adults aged between 32 and 84 years (mean: 64.2 years) with bilateral moderate-to-profound hearing loss (PTA3 ≥ 57 dB HL) who received a CI. The devices were among the two most modern generations at the time of the study: 15 participants used Cochlear® (N24 or Freedom 24RE series), 5 participants used Advanced Bionics (HR90k) and 2 participants used MED-EL™ (Combi40 and Sonata). All participants were assessed while wearing two hearing aids (before implantation) and monaurally with the CI ear after implantation. In addition, the 18 participants who used a hearing aid in the non-implanted ear were assessed while using the CI and the hearing aid (bimodal hearing). The (real ear) gain provided by the hearing aids was verified to match NAL-NL1 targets at 55, 60 and 70 dB SPL. All assessments were performed using recorded sounds presented at 60 or 70 dB A through a single loudspeaker positioned 1 m in front of the participant.

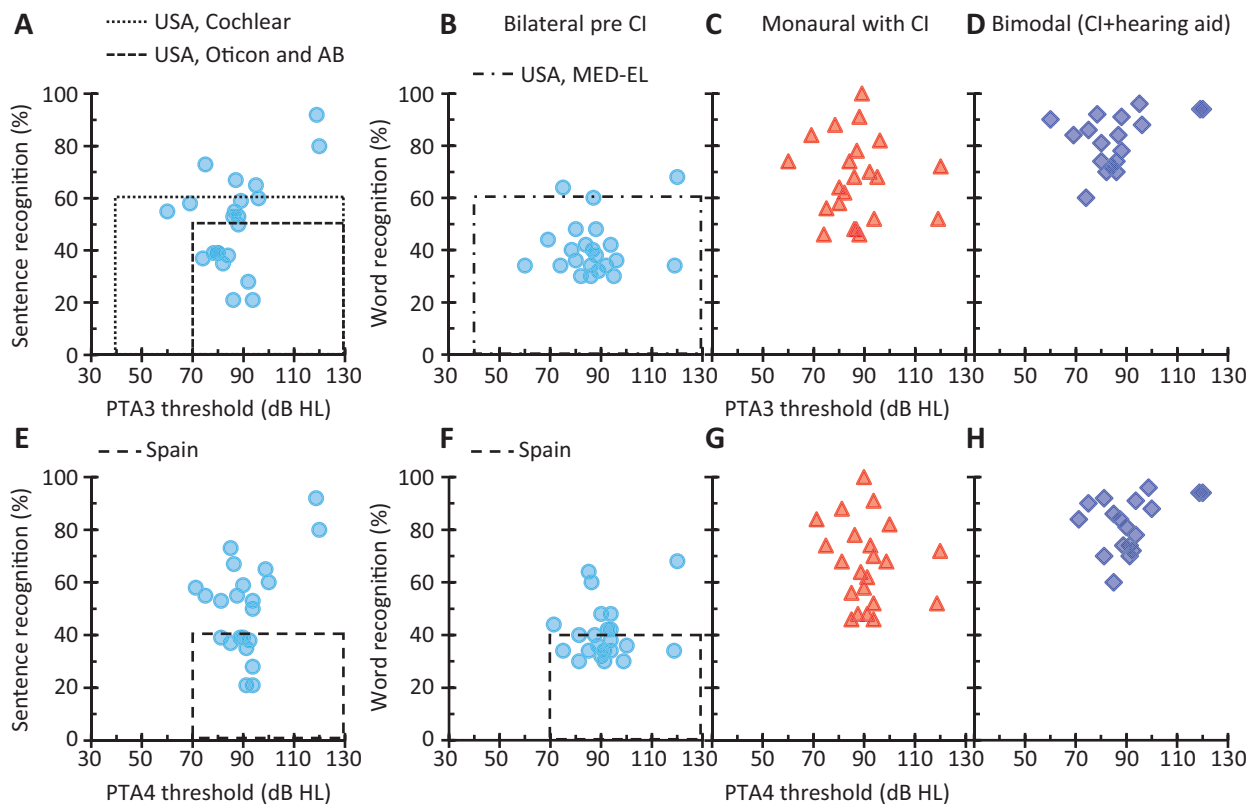


Figure 2. A. Recognition of sentences in quiet in the best-aided condition (with two hearing aids) as a function of PTA3 in the ear that later received a CI (N=22). Audiometric thresholds were measured without amplification. The dotted and dashed lines represent current CI candidacy criteria according to country and brand. Five participants did not qualify for a CI from the Cochlear, Oticon or AB brands in the United States. B. Like panel A, but for recognition of CNC words. C. Recognition of CNC words in quiet after receiving a CI (mean duration of use 17.9 months). Recognition was measured by presenting the words only to the CI ear, and it is plotted as a function of the audiometric thresholds obtained from the same ear before implantation. D. Like panel C, but when participants used a CI in one ear and a hearing aid in the other. E-H. Like panels A-D but as a function of PTA4. AB: Advanced Bionics. Data obtained from [Gifford et al. \(2010\)](#).

Figures 2A and 2E show sentence recognition before implantation as a function of PTA3 and PTA4, respectively. Five participants did not meet the candidacy criteria in the United States (Figure 2A). In Spain, only 9 of the 22 participants would have been CI candidates if we assume that the criterion “<40% in speech test” refers to sentence recognition (Figure 2E), and 13 of the 22 would have been candidates if we assume that the criterion refers to word recognition (Figure 2F). Twenty of the 22 participants showed better performance with a single CI (Figure 2C, G) than in the best-aided condition (i.e., with two hearing aids) before receiving the implant (Figure 2B, F). The mean improvement in this case was 27%. The 18 participants with bimodal hearing performed better with a CI and a hearing aid (Figure 2D, H) than with two hearing aids (Figure 2B, F), showing a mean improvement of 42%.

In summary, the results are consistent with Figure 1. First, individuals with $PTA3 \geq 60$ dB HL show better performance with a CI and a hearing aid than with two hearing aids. Second, even individuals who recognize more than 60% of the sentences can perform better after receiving an implant. In addition, the results demonstrate that the number of CI candidates would be greater if recognition was assessed using words instead of sentences, since word recognition is not affected by compensatory factors (such as inferring words from the context of the sentence) that can help recognize sentences ([Gifford et al., 2008, 2010](#)). The FDA indicates that recipients of MED-EL CIs should be examined using words rather than sentences. Specifically, word recognition must be $\leq 50\%$ in the ear to be implanted and $\leq 60\%$ in the non-implanted ear for an adult with bilateral hearing loss to qualify for MED-EL implant (Table 1). For reference, the

MED-EL criterion is indicated as bilateral recognition $\leq 60\%$ in Figure 2B, since it is likely that recognition in the non-implanted or implanted ear is also $\leq 60\%$. Therefore, all individuals in the study by Gifford et al. (2010), except for two of them, would be MED-EL CI candidates in the United States. It is unclear whether those two people would meet the criteria if each ear were assessed separately.

Amoodi et al. (2012) examined 27 adults aged between 26 and 89 years (mean: 54.6 years) with bilateral moderate-to-profound hearing loss (PTA3 ≥ 55 dB HL). Sixteen of them wore hearing aids in the two ears, 10 in one ear, and one participant did not use hearing aids. All of them received a CI (14 Advanced Bionics; 10 MED-EL; 3 Cochlear) between 2000 and 2010, and 24 of them continued to use a hearing aid in the non-implanted ear. As shown in Figure 3A, none of the participants met the CI candidacy criteria at the time of the study, since they showed HINT sentence recognition $\geq 60\%$ (circles in Figure 3A). Nevertheless, all showed better sentence recognition after receiving a CI (diamonds in Figure 3A), with a mean improvement of 27%. As in Gifford et al. (2010), participants showed poorer word recognition (circles in Figure 3B) than sentence recognition (circles in Figure 3A), so many participants would have been CI candidates if assessed using words. All participants showed better word recognition after receiving a CI without reaching 100%, i.e., without an

observed ceiling effect (diamonds in Figure 3B), with a mean improvement of 37%.

The study of Amoodi et al. (2012) is consistent with that of Gifford et al. (2010). First, it shows that individuals who are not currently eligible as CI candidates because their sentence recognition scores exceed 60% could perform better with a CI than with hearing aids. Second, it shows that word recognition is more sensitive than sentence recognition for determining CI candidacy, as it avoids ceiling effects.

Lastly, Quatre et al. (2020) examined individuals who did not meet the CI candidacy criteria of the French *Haute Autorité de Santé*: bilateral severe-to-profound sensorineural hearing loss together with speech discrimination in quiet $< 50\%$ using Fournier word lists (or equivalent) at 60 dB SPL and with optimized hearing aids. For monosyllabic word recognition presented in free field, the median score in the best listening condition was 41% before receiving the CI and 74% one year after the implantation (N=105 adults). Disyllabic word recognition in the best listening condition increased from 60% to 90% after implantation (N=160 adults).

An important question arising from the studies just reviewed is: which individuals would benefit from a CI if candidacy were based solely on word recognition in the best-aided condition? Based on the two studies that report individual data (Gifford et al., 2010; Amoodi et al., 2012), the average monosyllabic

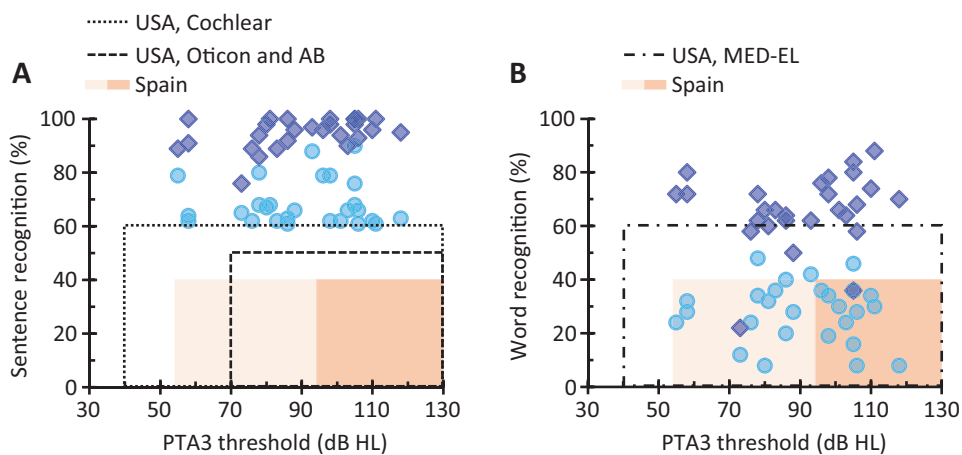


Figure 3. Recognition of HINT sentences (A) in quiet (N=19) or in noise at an SNR of +5 dB (N=8) and recognition of CNC words in quiet (B) in the best-aided condition (two ears) before (circles) and 12 months after (diamonds) receiving a CI. Speech was presented at 65 dB SPL. Recognition is plotted as a function of the PTA3 threshold for the implanted ear before receiving the CI. Audiometric thresholds were measured without amplification. The dotted and dashed lines indicate current CI candidacy criteria, according to country and brand. The dark orange area indicates that a person with the corresponding PTA3 qualifies for a CI in Spain, while the light orange area indicates that candidacy may depend on whether the PTA4—including the 4 kHz threshold—exceeds 70 dB HL. The orange areas are identical in the two panels because the Spanish CI candidacy criteria does not specify whether the “speech test” refers to sentences or words (Table 1). AB: Advanced Bionics. Data obtained from Amoodi et al. (2012).

word-recognition score after receiving a CI was 72%, with a standard deviation of 15%. Therefore, individuals with word recognition $\leq 57\%$ (mean minus one standard deviation) in the best-aided condition would be expected to experience significant improvement following cochlear implantation. This is consistent with the criteria proposed by recent studies (see the Discussion section).

The data reviewed so far refer to the adult population. A key question is whether children under 18 years who fall outside current CI candidacy criteria could benefit more from a CI than from a hearing aid. To answer this question, we reviewed data from [Carlson et al. \(2015\)](#). They examined 51 minors who had received a CI (age at implantation between 7 months and 17.6 years; mean: 8.3 years) despite not meeting the FDA candidacy guidelines. The guidelines at the time of the study were like the current ones (Table 1), except that implantation was not indicated in cases of unilateral or asymmetric hearing loss. [Carlson et al. \(2015\)](#) included children who met one or both of the following criteria: (1) a PTA3 below 70 dB HL in one or both ears if they were between 2 and 17 years old, or a PTA3 below 90 dB HL if they were younger than 2 years; or (2) a word and/or sentence recognition score greater than 30% with the best available hearing assistance. Participants were distributed into four groups. Group A included individuals with PTA3 <70 dB HL (or <90 dB HL for children under 2

years old) in the ear to be implanted (N=8). Group B comprised individuals who had PTA3 <70 dB HL (or <90 dB HL for children under 2 years old) in the contralateral ear (N=19). Group C included individuals who obtained a score greater than 30% in the ear to be implanted in age-appropriate word/sentence tests (N=24). Finally, Group D included individuals who obtained a score greater than 30% in the best-aided condition before implantation (N=42). The four groups were not mutually exclusive.

The range of audiometric thresholds in the implanted ear and speech recognition scores (words and sentences) in the best-aided condition for the entire sample are shown in Figure 4A (red line). Preoperative speech recognition scores ranged between 22% and 96% (mean = 58%) in the best-aided condition (red line in Figure 4A), and between 0% and 70% (mean = 25%) when listening with the implanted ear alone. Seventeen months after receiving a CI (44 Cochlear, 13 Advanced Bionics, 6 MED-EL), the mean speech recognition score was 88% with the implanted ear (Figure 4B) and 90% in the bimodal condition (CI + hearing aid) (Figure 4C). This represented an improvement in speech recognition of 63% and 31%, respectively. In addition, at the group level, children demonstrated more than 1 year of language growth per calendar year after receiving the CI.

The study of [Carlson et al. \(2015\)](#) demonstrates that children who do not meet current CI candidacy

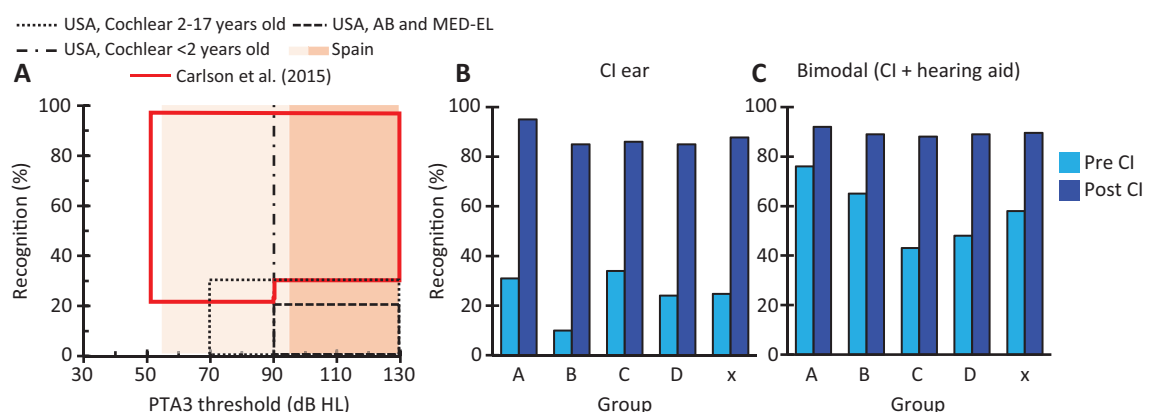


Figure 4. A. Characteristics of the participants of the study of [Carlson et al. \(2015\)](#) (red line). The dotted and dashed lines indicate the current CI candidacy criteria for minors (under 18 years of age) with bilateral hearing loss, according to country and brand. The dark orange area indicates that a person with the corresponding PTA3 qualifies for a CI in Spain, while the light orange area indicates that candidacy may depend on whether the PTA4—including the 4 kHz threshold—exceeds 70 dB HL. B. Mean word and sentence recognition with the implanted ear before (light blue) and after (dark blue) receiving the CI. Group A: PTA3 <70 dB HL (or <90 dB HL for children under 2 years of age) in the CI ear (N=8). Group B: PTA3 <70 dB HL (or <90 dB HL in children under 2 years) in the contralateral ear (N=19). Group C: >30% recognition with the ear to be implanted on age-appropriate word/sentence tests (N=24). Group D: >30% in the best-aided condition before implantation (N=42). \bar{x} = Mean. C. Like panel B, but when speech was perceived with bimodal stimulation (CI and contralateral hearing aid). Data from [Carlson et al. \(2015\)](#). AB: Advanced Bionics.

criteria show better recognition with a CI than with amplification. The authors suggest that “a large-scale reassessment of pediatric cochlear implant candidacy, including less severe hearing losses and higher preoperative speech recognition, is warranted to allow more children access to the benefits of cochlear implantation”.

The data reported by [Quatre et al. \(2020\)](#), cited above, are consistent with those of [Carlson et al. \(2015\)](#). For the pediatric population (age <18 years old), [Quatre et al. \(2020\)](#) indicate that the median score for monosyllabic word recognition increased from 48% in the best-aided condition before implantation to 82% with the combined use of CI and contralateral hearing aid one year after implantation (N=35). As for disyllabic word recognition, performance increased from 80% before implantation to 90% after implantation (N=75).

Speech recognition in noise

So far, we have reviewed the benefits of cochlear implantation for speech recognition in *quiet* among individuals who do not meet the current CI candidacy criteria. However, hearing-aid users usually experience greater difficulties recognizing speech in background noise than in quiet ([Peters et al., 1998](#)). Therefore, it is important to ask whether CIs also provide advantages over hearing aids in noisy conditions, particularly for individuals whose speech recognition in quiet exceeds the thresholds established by current CI indication guidelines. To address this question, we now review studies assessing speech recognition in quiet and noise among individuals who did not meet implantation criteria in their respective countries.

[Perkins et al. \(2021\)](#) examined people older than 16 (mean age: 68 years) with postlingual hearing loss who had received one (N=103) or two (N=1) CIs between 2009 and 2019. Participants received devices from different brands: 42 received Advanced Bionics, 34 Cochlear, and 28 MED-EL. For a subgroup of participants, both CNC word recognition and AzBio sentence recognition were measured in quiet and at +5 dB SNR in “speech babble” noise in the best-aided condition. Speech-recognition scores were obtained before implantation and at 6 and/or 12 months after CI activation, depending on participant availability. All tests were performed with recorded stimuli at 60 dB SPL presented through a single loudspeaker located 1 m in front of the participant. In addition, it

was verified that hearing aids provided the NAL-NL2 gain prescription for speech at 60 dB SPL.

Figure 5A shows that the mean word recognition score in quiet increased from 52% before implantation to 75% at 6–12 months after CI activation (N=83). Figure 5B shows that most participants showed better recognition after receiving a CI (values above zero), and that the benefit provided by CIs decreased as pre-CI performance increased, offering little or no benefit for individuals with pre-CI word recognition of 90% (Figure 5A). For AzBio sentences in quiet (N=80), the mean score increased from 70% before implantation to 87% at 6–12 months after CI activation (Figure 5C). Similar to word recognition, the benefit provided by the CI decreased as pre-CI performance increased (Figure 5D). Additionally, Figure 5C shows that more participants exhibited a ceiling effect (100% recognition) before implantation for sentences than for words (Figure 5A), consistent with findings described in previous sections. Consequently, few individuals would be CI candidates if candidacy were based on sentence recognition in quiet. However, when assessed with sentences in noise, many of those individuals would be eligible for implantation (Figure 5E). Moreover, most of them would achieve better performance with a CI and a hearing aid than with two hearing aids (Figure 5F). Overall, these results indicate that CIs can substantially improve speech recognition in noisy environments.

The study by [Mudery et al. \(2016\)](#) shows results consistent with those of [Perkins et al. \(2021\)](#). [Mudery et al. \(2016\)](#) examined 15 individuals (mean age: 73.3 years) who had received a CI between 2013 and 2015. AzBio sentence recognition in quiet was measured monaurally (right hearing aid only, left hearing aid only) and bilaterally. If the score was above 40% in the best-aided condition, sentence recognition in “speech babble” noise at +10 dB SNR was measured. If the score exceeded 40% in this condition, sentence recognition was measured at +5 dB SNR. Postoperative assessments were carried out at 3, 6 and 12 months after surgery. Ten individuals were examined in quiet and in noise, and all but one of them had preoperative sentence recognition with two hearing aids $\geq 58\%$ (mean = 74%) in quiet. After implantation, average sentence recognition in the best-aided condition increased by 10% (standard deviation 16%) in quiet, and by 42% (standard deviation 33%) in noise. As in the study of [Perkins et al.](#)

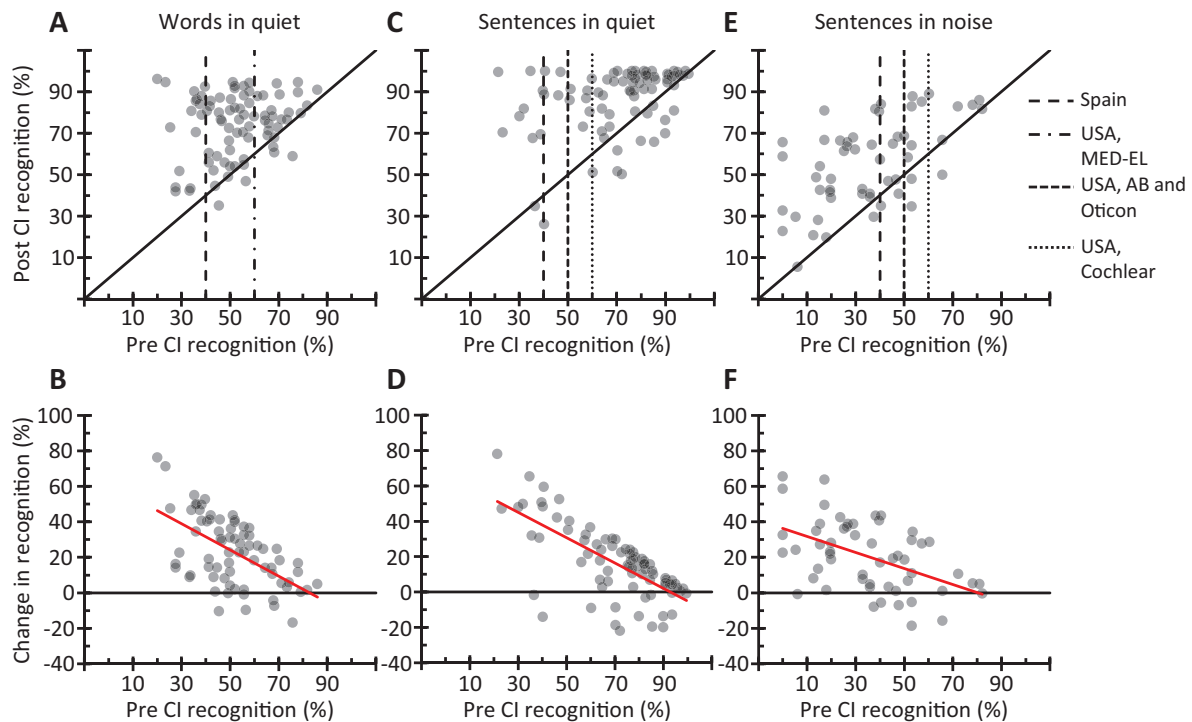


Figure 5. Upper panels: Recognition of CNC words (A), AzBio sentences in quiet (C), and AzBio sentences in noise at +5 dB SNR (E) in the best-aided condition before and after receiving a CI, i.e., with two hearing aids (pre-CI) versus a CI and a contralateral hearing aid (post-CI). The vertical lines show CI candidacy criteria for adults with bilateral hearing loss in different countries and for different brands (Table 1). AB: Advanced Bionics. Lower panels: Change in speech recognition after receiving a CI as a function of recognition before receiving the implant. Positive values represent better performance with a CI and hearing aid than with two hearing aids. Data adapted from Perkins et al. (2021).

(2021), the improvement in recognition after receiving a CI decreased as pre-CI performance increased. Therefore, the studies of Mudery et al. (2016) and Perkins et al. (2021) show that individuals with sentence recognition scores in quiet above 60% show better performance with a CI and a hearing aid than with two hearing aids for speech presented in both quiet and noise.

Satisfaction after receiving a CI

When determining the best treatment for a patient, it is important to consider not only potential improvements in speech recognition, but also possible gains in device satisfaction and overall quality of life. This section reviews the literature to examine whether individuals who do not meet current CI candidacy criteria could experience greater satisfaction and improved quality of life when using a CI combined with a hearing aid rather than two hearing aids.

In the study of Amoodi et al. (2012), described above, the authors examined a group of adults with

postlingual hearing loss. Their participants showed speech recognition above the commonly accepted criteria for implantation (Figure 2A) but were disappointed with their hearing aids. The authors used the Hearing Handicap Inventory (Newman et al., 1991) to assess the emotional and social impact of hearing loss before implantation and one year after implantation. They found that the average score decreased significantly after receiving a CI (from 67.9 to 35.4 points), which indicates a major improvement regarding self-perceived hearing disability. Amoodi et al. (2012) suggested that this improvement may be explained by the fact that participants experienced speech-recognition difficulties in their daily lives when using hearing aids, which were not detected when performance was assessed using HINT sentences in quiet.

Quatre et al. (2020) also assessed the quality of life of individuals who did not meet the CI criteria established by the French *Haute Autorité de Santé*. They examined 270 adult patients using the Categorical Auditory Performance (CAP) scale (Archbold et al., 1995), a hierarchical scale ranging from 1 to 7 that assesses a person's level of functional auditory

perception in daily-life situations. The assessment was performed before cochlear implantation and one year after surgery. The median score increased from 5 points before implantation to 6 points after implantation. This difference was statistically significant and indicates an improvement in functional auditory perception after receiving the CI. The mean communication difficulties, assessed using the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire (Cox & Alexander, 1995), were 53.4% before implantation and decreased to 30.5% after one year of CI use. Results also improved in specific situations. Particularly, difficulties in reverberant environments decreased from 69.4% to 56.3%, whereas in the presence of background noise they went from 73.4% to 57.1%. Lastly, regarding aversion to sounds, values decreased from 46.7% to 41.4%. For the pediatric population (age <18 years), Quatre et al. (2020) indicate that 40 patients were assessed using the CAP scale and that their median score increased from 5 to 7 after implantation.

Although the available evidence is limited, these studies suggest that patients who are close to meeting CI candidacy criteria may experience greater satisfaction with a CI than with hearing aids, particularly when they are dissatisfied with their hearing aids.

Discussion

Proposed CI prescription criteria

Cochlear implant candidacy criteria have evolved over time, and there is currently no unified international criterion. Although the FDA regards adults with moderate bilateral sensorineural hearing loss eligible for a CI (from MED-EL or Cochlear, Table 1), candidacy in most settings—and particularly in Spain—is generally limited to individuals with severe or profound hearing loss. The studies reviewed in this article suggest that individuals with moderate hearing loss could benefit from a CI. The American Academy of Otolaryngology–Head and Neck Surgery supports cochlear implantation in children older than 12 months whose PTA4 thresholds exceed 65 dB HL and who show a persistent or increasing gap in auditory and language skills (AAO-HNS, 2021). Leigh et al. (2016) (Figure 1A) and Zwolan et al. (2020) suggest that health professionals should consider referring patients for evaluation of CI candidacy when their PTA3 thresholds exceed 60–65 dB HL. The literature reviewed in the present

study (e.g., Amoodi et al., 2012; Gifford et al., 2010) is consistent with those recommendations.

Another criterion for CI candidacy is that speech recognition falls below a specified percentage, either in the best-aided condition in cases of bilateral hearing loss or in the ear to be implanted in cases of unilateral or asymmetric hearing loss. The exact threshold varies across countries (Table 1). Several studies have suggested that assessment with HINT sentences in quiet can lead to ceiling effects and, consequently, that this test is not appropriate for monitoring performance over time or for determining CI candidacy (Gifford et al., 2008; Firszt et al., 2004). AzBio sentences are more difficult to recognize than HINT sentences because they provide limited contextual cues, making it more difficult for the listener to predict unrecognized words. However, they still have sufficient semantic content to achieve higher recognition scores compared to monosyllabic words (Gifford et al., 2008) (Figure 5). Some studies suggest adopting the criterion of 60% recognition in the best-aided condition to establish CI candidacy, with this criterion being assessed using monosyllabic words (Zwolan et al., 2020; Zwolan & Basura, 2021) or AzBio sentences in noise (Mudery et al., 2016; Zwolan & Basura, 2021). In line with these investigations, the Minimum Speech Test Battery, used by health professionals to assess CI candidacy in the United States, has shifted from including HINT sentences to using AzBio sentences. These tests would add to monosyllabic word-in-quiet recognition, which has been part of the battery from the beginning (Zwolan & Basura, 2021; Dunn et al., 2024). In Spanish, there exist recordings of AzBio sentences (Rivas et al., 2021) and disyllabic words (Cárdenas & Marrero, 1994; Weisleder & Hodgson, 1989) but not of monosyllabic words (reviewed by Rodríguez-Ferreiro & Serra, 2024). Velandia et al. (2024) compared recognition of monosyllabic CNC words in English with that of disyllabic words in Spanish (Weisleder & Hodgson, 1989) and found that disyllabic words produced higher recognition scores. Therefore, there is a need to develop assessment materials in Spanish to evaluate CI candidacy in Spanish-speaking populations across different countries.

People who currently receive a CI

The available evidence suggests that patients who do not meet CI criteria but are close to doing so should be referred for candidacy evaluation, as they are likely to benefit more from CIs than from continued

hearing-aid use. This aligns with clinical practice in the United States, where over three-quarters of surveyed otolaryngologists report performing cochlear implantation outside the official FDA guidelines (Carlson et al., 2018). However, this stands in contrast to the fact that fewer than 10% of individuals with severe or profound hearing loss receive a CI (2.1% in the United States, 3% in Spain, 5% in the United Kingdom, 5.7% in Belgium and the Netherlands) (Beraza-Tamayo et al., 2023). These data highlight that thousands of people worldwide are not receiving the most effective treatment for their hearing loss.

Limitations

The aim of this article is to provide an evidence-based perspective on whether ‘borderline’ individuals who do not quite meet current implantation criteria could perform better with CIs than with hearing aids. Our focus was on individuals with bilateral hearing loss who were implanted with a single CI, since this is the most common case and the best documented one. Data for other cases are scarce or non-existent. For example, regarding individuals with unilateral or asymmetric hearing loss, we only found one relevant study (Bernstein et al., 2025). The study in question examined individuals with unilateral or asymmetric hearing loss (PTA4 \geq 59 dB HL and CNC word recognition $>$ 5% and $<$ 40% in the ear to be implanted) who did not meet current implantation criteria in the United States (Table 1). Notable improvements were observed when using only a CI, both in speech understanding and sound localization, as well as in perceived quality of life. These benefits were comparable to those of patients with unilateral or asymmetric hearing loss who met the $<$ 5% word recognition threshold. Therefore, the study suggests making CI candidacy criteria more flexible in cases of unilateral or asymmetric hearing loss.

With respect to the use of bilateral CIs by individuals with bilateral hearing loss who are considered “borderline” CI candidates, no relevant studies were found.

Regarding the pediatric population, three studies have been reviewed (Carlson et al., 2015, Leigh et al., 2016, Quatre et al., 2020). The study of Carlson et al. (2015) must be highlighted since it refers to criteria in the United States, which are among the most restrictive. Carlson et al. (2015) show that hearing-aid users with a speech-recognition score greater than 30% achieve better performance and show greater

language development with a CI and a contralateral hearing aid than with two hearing aids. This study highlights the paradox that cochlear implantation criteria are more stringent for children than for adults (Table 1), even though the early years of life are critical for language development. More research is needed to establish pediatric criteria based on scientific evidence.

Lastly, it is important to emphasize that, although CIs could benefit individuals who do not meet current implantation criteria, implantation involves surgery under general anesthesia. This carries inherent risks and requires a longer period of audiological rehabilitation compared with hearing aids. Consequently, the initial cost of a CI is higher (Benifla et al., 2024), a factor that is particularly relevant in lower-income regions. Nevertheless, while country-specific considerations must be considered, CIs remain a cost-effective intervention in the long term (Gatto et al., 2024; Neve et al., 2021).

Conclusions

This research investigated whether ‘borderline’ patients who do not reach severe hearing loss can show better performance with a CI than with one or two hearing aids. The reviewed scientific evidence shows that patients with PTA3 thresholds \geq 65 dB HL have an 80% likelihood of performing better with a CI than with one or two hearing aids. The evidence also shows that individuals with a preoperative monosyllabic word recognition score lower than 60% in the best-aided condition (with two hearing aids) will perform better with a CI and a contralateral hearing aid than with bilateral hearing aids. On the other hand, for ‘borderline’ candidates, implantation reduces the emotional and social impact of hearing loss and increases quality of life. Our findings are consistent with recent studies and international reports, which suggest that individuals who have audiometric thresholds $>$ 60–65 dB HL and word recognition scores $<$ 60% in the best-aided condition should be referred for CI candidacy evaluation.

References

- Alkaf, F. M., & Firszt, J. B. (2007). Speech recognition in quiet and noise in borderline cochlear implant candidates. *J Am Acad Audiol*, 18(10), 872-82. <https://doi.org/10.3766/jaaa.18.10.6>

- American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) (2021). *Position statement: Pediatric cochlear implantation candidacy*. <https://www.entnet.org/resource/position-statement-pediatric-cochlear-implantation-candidacy/>
- Amoodi, H. A., Mick, P. T., Shipp, D. B., Friesen, L. M., Nedzelski, J. M., Chen, J. M., & Lin, V. Y. (2012). Results with cochlear implantation in adults with speech recognition scores exceeding current criteria. *Otol Neurotol*, 33(1), 6-12. <https://doi.org/10.1097/MAO.0b013e318239e5a1>
- Archbold, S., Lutman, M. E., & Marshall, D. H. (1995). Categories of Auditory Performance. *Ann Otol Rhinol Laryngol* 106, 312-314.
- Benifla, M., Martelli, N., Brenet, E., Compagnon, C., Dubernard, X., & Labrousse, M. (2024). Costs analysis of cochlear implantation in children. *European Annals of Otorhinolaryngology, Head and Neck Diseases*, 14(4), 209-213. <https://doi.org/10.1016/j.anori.2024.02.012>
- Beraza-Tamayo, N., Cenjor-Español, C., Gómez-Pajuelo, P., Jáudenes-Casaubón, C., Manrique, M., Nuñez, F., de-Raeve, L., Ramos, A., & Zamora, J. (2023). *Libro blanco sobre implantes cocleares en adultos y ancianos*. GAES
- Bernstein, J. G. W., Pillion, E. M., & Tolisano, A. M. (2025). Clinical Outcomes for Adult Single-Sided Deafness Cochlear. Implantees Exceeding the 5% Candidacy Criterion. *Ear Hear*, 46(2), 336-346. <https://doi.org/10.1097/AUD.0000000000001578>
- British Deaf Association (2015). *Fast facts about the Deaf community*. <https://bda.org.uk/fast-facts-about-the-deaf-community/>
- Byrne, D., Dillon, H., Ching, T., Katsch, R., & Keidser, G. (2001). NAL-NL1 procedure for fitting nonlinear hearing aids: characteristics and comparisons with other procedures. *J Am Acad Audiol*, 12(1), 37-51.
- Cárdenas, M., & Marrero, V. (1994). *Cuaderno de logaudiometría*. Universidad Nacional de Educación a Distancia.
- Carlson, M. L., Sladen, D. P., Gurgel, R. K., Tombers, N. M., Lohse, C. M., & Driscoll, C. L. (2018). Survey of the American Neurotology Society on Cochlear Implantation: Part 1, Candidacy Assessment and Expanding Indications. *Otol Neurotol*, 39(1), e12-e19. <https://doi.org/10.1097/MAO.0000000000001632>
- Carlson, M. L., Sladen, D. P., Haynes, D. S., Driscoll, C. L., DeJong, M. D., Erickson, H. C., Sunderhaus, L. W., Hedley-Williams, A., Rosenzweig, E. A., Davis, T. J., & Gifford, R. H. (2015). Evidence for the expansion of pediatric cochlear implant candidacy. *Otol Neurotol*, 36(1), 43-50. <https://doi.org/10.1097/MAO.0000000000000607>
- Carlyon, R. P., & Goehring, T. (2021). Cochlear Implant Research and Development in the Twenty-first Century: A Critical Update. *J Assoc Res Otolaryngol*, 22(5), 481-508. <https://doi.org/10.1007/s10162-021-00811-5>
- Cox, R. M., & Alexander, G. C. (1995). The abbreviated profile of hearing aid benefit. *Ear Hear*, 16(2), 176-86. <https://doi.org/10.1097/00003446-199504000-00005>
- Davies-Venn, E., Souza, P., Brennan, M., & Stecker, G. C. (2009). Effects of audibility and multichannel wide dynamic range compression on consonant recognition for listeners with severe hearing loss. *Ear Hear*, 30(5), 494-504. <https://doi.org/10.1097/AUD.0b013e3181a6e5bc>
- Dorman, M. F., Loizou, P. C., Kemp, L. L., & Kirk, K. I. (2000). Word recognition by children listening to speech processed into a small number of channels: data from normal-hearing children and children with cochlear implants. *Ear Hear*, 21(6), 590-596. <https://doi.org/10.1097/00003446-200012000-00006>
- Dunn, C. C., Zwolan, T. A., Balkany, T. J., Strader, H. L., Biever, A., Gifford, R. H., Hall, M. W., Holcomb, M. A., Hill, H., King, E. R., Larky, J., Presley, R., Reed, M., Shapiro, W. H., Sydlowski, S. A., Wolfe, J. (2024). A Consensus to Revise the Minimum Speech Test Battery-Version 3. *Am J Audiol*, 33(3), 624-647. https://doi.org/10.1044/2024_AJA-24-00008.
- Firszt, J. B., Holden, L. K., Skinner, M. W., Tobey, E. A., Peterson, A., Gaggl, W., Runge-Samuelsen, C. L., & Wackym, P. A. (2004). Recognition of speech presented at soft to loud levels by adult cochlear implant recipients of three cochlear implant systems. *Ear Hear*, 25(4), 375-87. doi: <https://doi.org/10.1097/01.aud.0000134552.22205.ee>
- Food and Drug Administration (FDA). (2024). *Summary of safety and effectiveness data: Premarket Approval Application (PMA) Number: P000025/S129*. <https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma.cfm?ID=P000025S129>
- Gatto, A., Tofanelli, M., Valentinuz, G., Mascherin, A., Costariol, L., Rizzo, S., Borsetto, D., Boscolo-Rizzo, P., & Tirelli, G. (2024). Cochlear implant cost analysis in adults: a European narrative review. *Eur Arch Otorhinolaryngol*, 281(9), 4455-4471. <https://doi.org/10.1007/s00405-024-08591-3>
- Gifford, R. H., Dorman, M. F., Shallop, J. K., & Sydlowski, S. A. (2010). Evidence for the expansion of adult cochlear implant candidacy. *Ear Hear*, 31(2), 186-94. <https://doi.org/10.1097/AUD.0b013e3181c6b831>
- Gifford, R. H., Shallop, J. K., & Peterson, A. M. (2008). Speech recognition materials and ceiling effects: considerations for cochlear implant programs. *Audiol Neurootol*, 13(3), 193-205. <https://doi.org/10.1159/000113510>
- Hainarosie, M., Zainea, V., & Hainarosie, R. (2014). The evolution of cochlear implant technology and its clinical relevance. *J Med Life*, 7(Spec Iss 2), 1-4.
- Johannesen, P. T., Pérez-González, P., & Lopez-Poveda, E. A. (2014). Across-frequency behavioral estimates of the contribution of inner and outer hair cell dysfunction to individualized audiometric loss. *Front Neurosci*, 8 214. <https://doi.org/10.3389/fnins.2014.00214>
- Jorgensen, L. E., Benson, E. A., & McCreery, R. W. (2018). Conventional Amplification for Children and Adults with Severe-to-Profound Hearing Loss. *Semin Hear*, 39(4), 364-376. <https://doi.org/10.1055/s-0038-1670699>
- Kirk, K. I., Pisoni, D. B., & Osberger, M. J. (1995). Lexical effects on spoken word recognition by pediatric cochlear implant users. *Ear Hear*, 16(5):470-81. <https://doi.org/10.1097/00003446-199510000-00004>
- Leigh, J. R., Dettman, S. J., & Dowell, R. C. (2016). Evidence-based guidelines for recommending cochlear implantation for young children:

- Audiological criteria and optimizing age at implantation. *Int J Audiol*, 55(Suppl 2), S9-S18. <https://doi.org/10.3109/14992027.2016.1157268>
- Leigh-Hunt, N., Bagguley, D., Bash, K., Turner, V., Turnbull, S., Valtorta, N., & Caan, W. (2017). An overview of systematic reviews on the public health consequences of social isolation and loneliness. *Public Health* 152, 157-171. <https://doi.org/10.1016/j.puhe.2017.07.035>
- Livingston, G., Huntley, J., Liu, K. Y., Costafreda, S. G., Selbæk, G., Alladi, S., Ames, D., Banerjee, S., Burns, A., Brayne, C., Fox, N. C., Ferri, C. P., Gitlin, L. N., Howard, R., Kales, H. C., Kivimäki, M., Larson, E. B., Nakasujja, N., Rockwood, K., ..., & Mukadam, N. (2024). Dementia prevention, intervention, and care: 2024 report of the Lancet standing Commission. *The Lancet*, 404(10452), 572-628. [https://doi.org/10.1016/S0140-6736\(24\)01296-0](https://doi.org/10.1016/S0140-6736(24)01296-0)
- Lopez-Poveda, E. A., Eustaquio-Martín, A., Fumero, M. J., Gorospe, J. M., Polo López, R., Gutiérrez Revilla, M. A., Schatzer, R., Nopp, P., & Stohl, J. S. (2020). Speech-in-noise recognition with more realistic implementations of a binaural cochlear-implant sound coding strategy inspired by the medial olivocochlear reflex. *Ear and Hearing*, 41(6), 1492-1510. <https://doi.org/10.1097/AUD.0000000000000880>
- Lopez-Poveda, E. A., Eustaquio-Martin, A., Stohl, J. S., Wolford, R. D., Schatzer, R., Gorospe, J. M., Santa Cruz Ruiz, S., Benito, F., & Wilson, B. S. (2017). Intelligibility in speech maskers with a binaural cochlear implant sound coding strategy inspired by the contralateral medial olivocochlear reflex. *Hearing Research*, 348, 134-137. <https://doi.org/10.1016/j.heares.2017.02.003>
- Lopez-Poveda, E. A., Eustaquio-Martin, A., Stohl, J. S., Wolford, R. D., Schatzer, R., & Wilson, B. S. (2016). A binaural cochlear implant sound coding strategy inspired by the contralateral medial olivocochlear reflex. *Ear and Hearing*, 37(3), e138-e148. <https://doi.org/10.1097/AUD.0000000000000273>
- Lopez-Poveda, E. A., Johannesen, P. T., Pérez-González, P., Blanco, J. L., Kalluri, S., & Edwards, B. (2017). Predictors of hearing aid outcomes. *Trends Hear*, 21, 1-28. <https://doi.org/10.1177/2331216517730526>.
- Manrique, M., Ramos, Á., de Paula Vernetta, C., Gil-Carcedo, E., Lassaletta, L., Sanchez-Cuadrado, I., Espinosa, J. M., Batuecas, Á., Cenjor, C., Lavilla, M. J., Núñez, F., Cavalle, L., & Huarte, A. (2017). Guía clínica sobre implantes cocleares. *Acta Otorrinolaringol Esp*, 70(1), 47-54. <https://doi.org/10.1016/j.otorri.2017.10.007>.
- Mudery, J. A., Francis, R., McCrary, H., & Jacob, A. (2016). Older Individuals Meeting Medicare Cochlear Implant Candidacy Criteria in Noise but Not in Quiet: Are These Patients Improved by Surgery? *Otol Neurotol*, 38(2), 187-191. <https://doi.org/10.1097/MAO.0000000000001271>
- National Institute for Health and Care Excellence (NICE) (2019). *Cochlear implants for children and adults with severe to profound deafness* (TA566). www.nice.org.uk/guidance/ta566
- Neve, O. M., Boerman, J. A., van den Hout, W. B., Briare, J. J., van Benthem, P. P. G., & Frijns, J. H. M. (2021). Cost-benefit Analysis of Cochlear Implants: A Societal Perspective. *Ear Hear*, 42(5), 1338-1350. <https://doi.org/10.1097/AUD.0000000000001021>
- Newman, C. W., Weinstein, B. E., Jacobson, G. P., & Hug, G. A. (1991). Test-retest reliability of the Hearing Handicap Inventory for Adults. *Ear Hear*, 12, 355-357. <https://doi.org/10.1097/00003446-199110000-00009>
- Nilsson, M., Soli, S. D., & Sullivan, J. A. (1994). Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. *J Acoust Soc Am*, 95(2), 1085-99. <https://doi.org/10.1121/1.408469>
- Organización mundial de la salud (OMS) (2021). *World report on hearing*. <https://www.who.int/publications/i/item/9789240020481>
- Organización mundial de la salud (OMS) (2025). *Sordera y pérdida de la audición*. <https://www.who.int/es/news-room/fact-sheets/detail/deafness-and-hearing-loss>
- Park, L. R., Gagnon, E. B., & Brown, K. D. (2021). The Limitations of FDA Criteria: Inconsistencies with Clinical Practice, Findings, and Adult Criteria as a Barrier to Pediatric Implantation. *Semin Hear*, 42(4), 373-380. <https://doi.org/10.1055/s-0041-1739370>
- Perkins, E., Dietrich, M. S., Manzoor, N., O'Malley, M., Bennett, M., Rivas, A., Haynes, D., Labadie, R., & Gifford, R. (2021). Further Evidence for the Expansion of Adult Cochlear Implant Candidacy Criteria. *Otol Neurotol*, 42(6), 815-823. <https://doi.org/10.1097/MAO.00000000000003068>
- Peters, R. W., Moore, B. C., & Baer, T. (1998). Speech reception thresholds in noise with and without spectral and temporal dips for hearing-impaired and normally hearing people. *J Acoust Soc Am*, 103(1), 577-87. <https://doi.org/10.1121/1.421128>
- Peterson, G. E., & Lehiste, I. (1962). Revised CNC lists for auditory tests. *J Speech Hear Disord*, 27, 62-70. <https://doi.org/10.1044/jshd.2701.62>
- Quatre, R., Fabre, C., Aubry, K., Bordure, P., Bozorg-Grayeli, A., Deguine, O., Eyermann, C., Franco-Vidal, V., Godey, B., Guevara, N., Karkas, A., Klopp, N., Labrousse, M., Lebreton, J. P., Lerosey, &, Lescanne, E., Loundon, N., Marianowski, R., ..., & Schmerber, S. (2020). The French Cochlear Implant Registry (EPIIC): Cochlear implant candidacy assessment of off-label indications. *Eur Ann Otorhinolaryngol Head Neck Dis*, 137(Suppl 1), S27-S35. <https://doi.org/10.1016/j.anorl.2020.07.012>
- Rivas, A., Perkins, E., Rivas, A., Rincon, L. A., Litvak, L., Spahr, T., Dorman, M., Kessler, D., & Gifford, R. (2021). Development and Validation of the Spanish AzBio Sentence Corpus. *Otol Neurotol*, 42(1), 154-158. <https://doi.org/10.1097/mao.0000000000002970>
- Rodríguez-Ferreiro, M., & Serra, V. (2024). Pruebas de habla en ruido: una revisión de las pruebas disponibles en español. *Auditio*, 8, e113. <https://doi.org/10.51445/sja.auditio.vol8.2024.113>
- Shukla, A., Harper, M., Pedersen, E., Goman, A., Suen, J. J., Price, C., Applebaum, J., Hoyer, M., Lin, F. R., & Reed, N. S. (2020). Hearing loss, loneliness, and social isolation: a systematic review. *Otolaryngol Head Neck Surg* 162, 622-633. <https://doi.org/10.1177/0194599820910377>
- Souza, P. E., Boike, K. T., Witherell, K., & Tremblay, K. (2007). Prediction of speech recognition from audibility in older listeners with hearing loss: effects of age, amplification, and background noise. *J Am Acad Audiol*, 18(1), 54-65. <https://doi.org/10.3766/jaaa.18.1.5>

- Summers, V., Makashay, M. J., Theodoroff, S. M., & Leek, M. R. (2013). Suprathreshold auditory processing and speech perception in noise: hearing-impaired and normal-hearing listeners. *J Am Acad Audiol* 24(4), 274-92. <https://doi.org/10.3766/jaaa.24.4.4>
- Velandia, S. L., Prentiss, S. M., Martínez, D. M., Sanchez, C. M., Laffitte-Lopez, D., & Snapp, H. A. (2024). Classification performance of Spanish and English word recognition testing to identify cochlear implant candidates. *Int J Audiol*, 1-7. <https://doi.org/10.1080/14992027.2024.2427854>
- Weisleder, P., & Hodgson, W. R. (1989). Evaluation of four Spanish word-recognition-ability lists. *Ear Hear* 10(6), 387-92. <https://doi.org/10.1097/00003446-198912000-00012>
- Zhang, Y., Johannesen, P. T., Molaee-Ardekani, B., Wijetillake, A., Attili Chiea, R., Hasan, P.-Y., Segovia-Martínez, M., & Lopez-Poveda, E. A. (2025). Comparison of performance for cochlear-implant listeners using audio processing strategies based on short-time FFT or spectral feature extraction. *Ear Hear* 46(1), 163-183. <https://doi.org/10.1097/AUD.0000000000001565>
- Zwolan, T. A., & Basura, G. (2021). Determining Cochlear Implant Candidacy in Adults: Limitations, Expansions, and Opportunities for Improvement. *Semin Hear*, 42(4), 331-341. <https://doi.org/10.1055/s-0041-1739283>
- Zwolan, T. A., Schvartz-Leyzac, K. C., & Pleasant, T. (2020). Development of a 60/60 Guideline for Referring Adults for a Traditional Cochlear Implant Candidacy Evaluation. *Otol Neurotol*, 41(7), 895-900. <https://doi.org/10.1097/MAO.0000000000002664>

Conflict of interest

The author declares that there is no conflict of interest.

Author contributions

The authors contributed equally to this work.

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