Hearing aids plus cochlear implants: Optimizing the bimodal pediatric fitting

By Steven A. Huart and Carol A. Sammeth

THE ARGUMENT FOR FITTING BIMODALLY

If you see a child tomorrow with a hearing loss in both ears, will you recommend one hearing aid or two? The obvious answer is two. You would have a hard time finding a dispensing professional today who does not agree that the benefits of bilateral hearing aid fitting make it the standard of care for those with binaural hearing loss.

While the benefits of binaural hearing and the advantage of bilateral fitting are beyond the scope of this article (e.g., see Litovsky et al.,[1] Kochkin[2]), these facts are undisputed in hearing healthcare circles. The industry's confidence in bilateral hearing aids is supported by current trends in fitting. In 1980 only 27% of hearing aid fittings were bilateral.[3] Today, it is an amazing 86% for those with binaural hearing loss.[4]

So, what is bimodal fitting and why should dispensing professionals care? Bimodal fitting means different stimuli are presented to each ear. For the purposes of this paper, it means a cochlear implant in one ear and a hearing aid in the other. But, you may ask, don't cochlear implant audiologists take care of that? The answer is no, at least not usually. Personal experience (first author), communication with cochlear implant audiologists, and the literature[5] suggest that most hearing aids in bimodal devices are fitted outside the cochlear implant center. Thus, if you have a patient who receives a cochlear implant in one ear, you will most likely be the one responsible for the continuing care of the hearing aid in the contralateral ear. It is in the best interests of both your patient and you to know how to optimize the hearing aid fitting for the best bimodal performance.

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If you fit hearing aids on children, the question is not *if* you will be responsible for managing a child with bimodal devices, but rather *when*. The number of unilateral cochlear implant recipients who continue to use contralateral hearing aids is clearly increasing (Figure 1). The conventional wisdom that cochlear implants and hearing aids should not be used simultaneously is archaic,[6,7] as we will show in this paper.

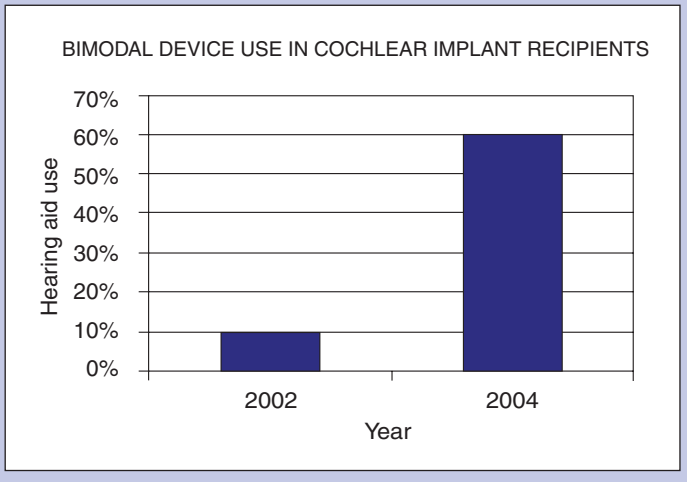

Figure 1. *Percentage of unilateral cochlear implant users choosing to wear a hearing aid in the contralateral ear. Sources: Tyler et al.,[8] Cowan and Chin-Lenn.[9]*

BIMODAL DEVICE USE IN CI WEARERS

Significant advances over the years in cochlear implant technology, speech-coding strategies, and surgical techniques have resulted in substantial improvements in the auditory-only speech-understanding abilities of cochlear implant recipients.[10] As a result, the candidacy criteria approved for cochlear implantation in the United States has progressively expanded.

When Cochlear Corporation, Ltd., introduced the original Nucleus® cochlear implant in 1985, the only candidates approved by the Food and Drug Administration were adults with profound bilateral sensorineural hearing loss of post-linguistic origin who had 0% open-set speech recognition using hearing aids. Now, under the FDA criteria approved in 2005, candidates can be adults or children aged 12 months and older, and can have either pre- or post-lingual onset of hearing loss. Although mid- and high-frequency hearing must still be profound (hearing thresholds >90 dB HL), low-frequency hearing loss can be moderate for adults (hearing thresholds >40 dB HL) and severe for children over age 2 (hearing thresholds >70 dB HL). Further, best-aided pre-operative speech-recognition criteria have been raised from 0% to <60%. Figure 2 shows the current criteria for each age group.

For persons with bilaterally profound sensorineural deafness (the purple-shaded area in Figure 2), cochlear

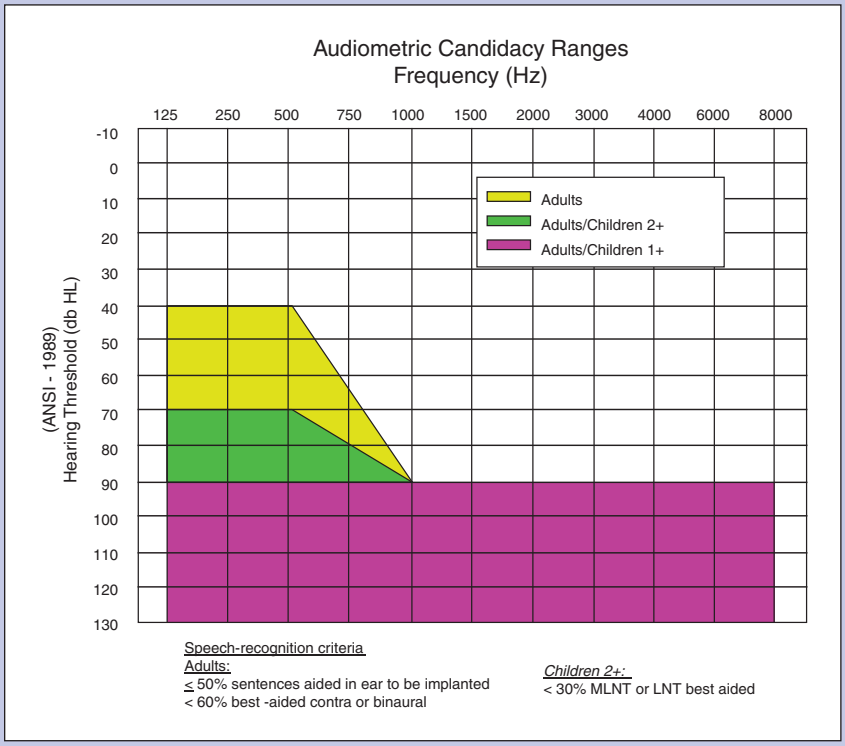

Figure 2. *Current FDA-approved audiometric and speech-recognition criteria for cochlear implantation with the Nucleus device, by age group. (For children, the open-set word-recognition test recommended is the Lexical Neighborhood Test [LNT] or Multisyllabic Lexical Neighborhood Test [MLNT], which are available from www.auditec.com.)*

implants are clearly the intervention of choice because many obtain little or no benefit from hearing aids. However, for children aged 2 years and up and for adults, there is a range of low-frequency thresholds (the green and yellow areas, respectively) that fall within the approved audiometric range for cochlear implants. Hearing aids often fail to provide adequate performance for these patients,[11] but a unilateral cochlear implant alone does not provide all the known benefits that arise from listening with two ears rather than one.

Binaural benefits from perception of interaural differences in time and intensity are well known to improve speech-recognition performance, particularly in background noise, due to a combination of head shadow, binaural redundancy, and binaural squelch effects (e.g., see Byrne, 1981[12] for a review). Further, bilateral inputs provide the potential for good localization ability. Finally, a strong argument can be made for bilateral stimulation, especially in children, in light of the impact of auditory deprivation on perception. When a hearing-impaired ear remains unaided, speech-recognition ability in that ear significantly deteriorates over time,[13,14] and there appears to be a limited window of opportunity for auditory system stimulation if the patient is to achieve maximal binaural functioning.[15]

Bilateral implantation is not for everyone. For example, there might be significant usable hearing in one ear. There may be insurance reimbursement or financial barriers. Parents may worry about surgery or preserving one ear for possible future technology or treatments.

These concerns may or may not be well-founded. Insurance reimbursement is not the obstacle it once was. Cochlear brand implants are designed to be "backward compatible" so future advances can be applied to implants done today. Cotanche reported that treatment, e.g., hair cell regeneration, may be 20 years or more away.[16] However, unilateral versus bilateral implantation in children is ultimately the parents' choice and their wishes must be respected. The less expensive, non-invasive fitting of a hearing aid on the ear contralateral to a cochlear implant allows preservation of hearing in that ear and may provide the benefits of binaural stimulation.

SUMMARY OF THE LITERATURE

The bimodal fitting approach was first reported in the literature in the early 1990s (e.g., Shallop et al., 1992[17]). Concerns were initially expressed that patients might be unable to combine the two very different sound sources for central processing. Fortunately, this has not proven to be the case. In fact, some researchers have argued that bimodal stimulation may provide "complementary" cues for processing of signals that may be advantageous to speech perception.[18]

Specifically, the lower frequencies provided by the hearing aid can provide information about the fundamental frequencies of a talker's voice and vowel information, while the mid- and high-frequency information from the cochlear implant can provide information needed on manner and place of articulation of consonants. It has also been suggested that localization ability, sound quality, and music perception may be enhanced by bimodal devices compared with bilateral cochlear implants.[19,20]

Studies have reported significant speech-recognition improvements for bimodal listening compared to either the patients' pre-operative bilateral hearing aid use or their post-operative use of the hearing aid or cochlear implant alone. This has been shown in adults[17,21-23] and in children.[24-26]

For example, in a study by Luntz et al.,[26] 12 subjects (3 post-lingually impaired adults and 9 pre-lingually impaired adults and children aged 7 and older) were tested on sentences in noise after 7 to 12 months of using bimodal devices. Both speech (at 55 dB HL) and noise (at 45 dB HL) were presented from a frontal loudspeaker. Average speech-recognition scores were only 12.9% for the hearing aid alone and 60.7% for the cochlear implant alone, but bimodal listening produced an average score of 75.6% correct.

Localization abilities have been shown to improve with bimodal devices relative to use of either device alone for some, although not all, adult[27,28] and pediatric[1,24] patients. Many users of bimodal devices have also reported higher levels of satisfaction and perceived benefit than with hearing aids worn pre-implantation, although cosmetic and handling concerns of using the two devices have sometimes been expressed,[29] emphasizing the need

for sufficient counseling and training. It is also important to consider that children may need more time to learn to use bimodal cues.[25]

There is debate over the relative effectiveness of bilateral cochlear implants versus bimodal devices. Overall, however, the published literature on bimodal devices has been quite positive (e.g. see Ching et al. for a review[18]). A judicious approach would be to fit a hearing aid contralaterally to the implant on patients who show sufficient benefit from the hearing aid and are able to use the binaural cues provided.

FACTORS IN FITTING THE HEARING AID

Certain aspects of the fitting need to be considered and possibly modified for optimal use of bimodal devices. Dispensing professionals who follow proven, evidence-based protocols for hearing aid fitting, however, will require minimal adaptation of their normal procedure. The American Academy of Audiology has published a Pediatric Amplification Protocol and all professionals dispensing hearing aids to children should be familiar with it.[30]

Optimization of the hearing aid in bimodal fittings essentially requires three steps. First, the cochlear implant map must be stable. You will need to communicate with the cochlear implant audiologist to know when this has been accomplished.

Second, a frequency response should be selected for the hearing aid that will provide the best speech intelligibility. This is established by starting with a hearing aid that has been fitted and verified using a prescriptive formula. While the first author has had success using NAL-NL1,[31] and Ching recommended it as an optimal starting point,[32] those who are proficient with DSL[i/o][33] or another validated prescriptive approach should not be discouraged from using it as the starting point.

From the initial prescription, two alternate frequency responses should be programmed into the hearing aid and adjusted for equal loudness. This is easy in multiple-memory digital hearing aids. As the limits of the hearing aid permit, program one should be the selected prescriptive formula frequency response. Program two should have 6-dB per octave *less* amplification in the low frequencies (-6 dB at 1000 Hz, -12 dB at 500 Hz,

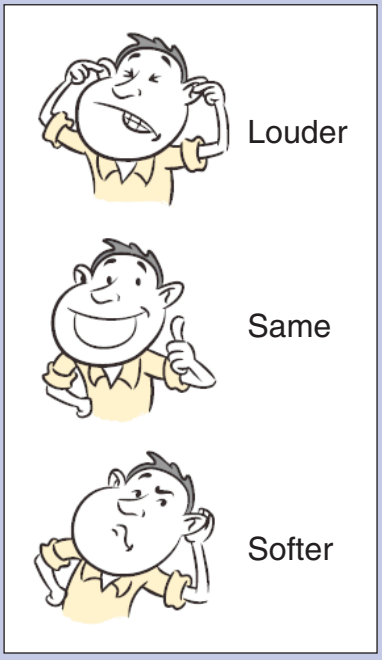

Figure 3. *Loudness balancing scale. Source: Cochlear in-house material.*

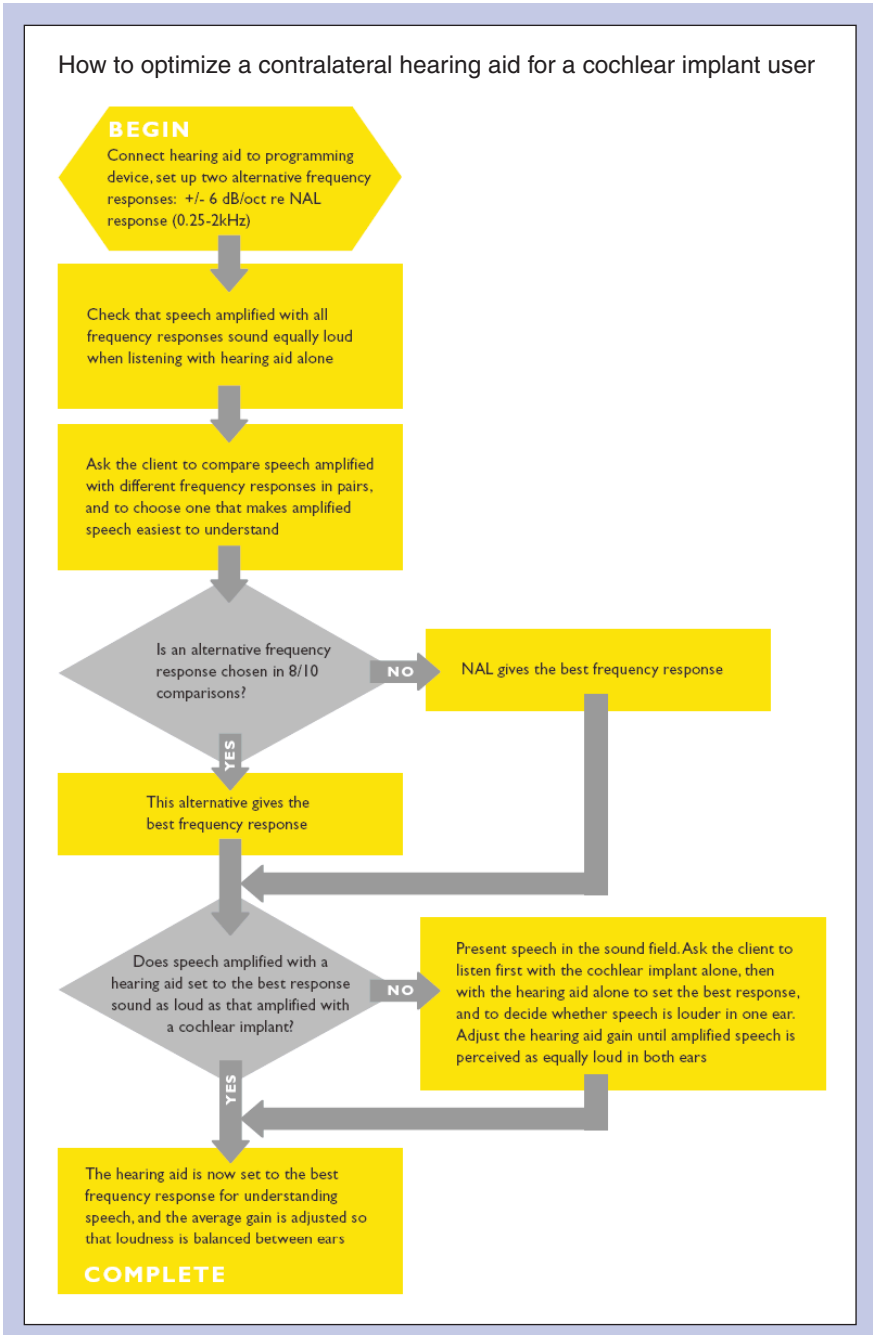

Figure 4. *Optimizing the hearing aid in bimodal fitting. Source: Cochlear in-house material.*

and -18 dB at 250 Hz). Program three should have 6-dB per octave *more* amplification in the low frequencies (+6 dB at 1000 Hz, +12 dB at 500 Hz, and +18 dB at 250 Hz).

Once the programs are established, the child should listen to connected discourse while the audiologist switches between programs to determine which one provides the clearest speech. This can be done by playing a recorded story or watching a child-friendly video. The cochlear implant should be turned off during this frequency response selection process. Ching reported that this procedure is appropriate for children as young as 6 years.[32] For younger children, the professional may choose to default to the prescriptive response.

Finally, the third step in the fitting protocol is to match overall loudness between the hearing aid and cochlear implant. Both the implant and the aid are turned on and the child is asked to report if the hearing aid is louder or softer than the cochlear implant. The aid is then adjusted accordingly. This can also be done while the child listens to a recorded story or watches a video. A chart like that in Figure 3 can be helpful for this task. Some children might experience loudness discomfort from amplification. If so, Ullauri et al. suggest starting with a lower volume setting on the hearing aid and raising it over time as acclimatization occurs until the level of balanced loudness is achieved.[34]

A flow chart for fitting the hearing aid in bimodal devices is shown in Figure 4. This recommended protocol has been validated in children and found to provide good binaural benefits.[24] For the reader wishing more in-depth training, a tutorial is available at www.cochlearcollege.com. Ching et al. have also published excellent articles on fitting and adjusting the hearing aid for children wearing bimodal devices.[2,35]

CONCLUSIONS

The use of bimodal devices is the recommended treatment option for children who meet cochlear implant candidacy but who either have some usable hearing in one ear or for other reasons get only one implant. Bimodal devices can be a successful alternative to bilateral hearing aids or to one cochlear implant alone.

It is important to remember these three vital rules: (1) Work with the implant center to make sure the implant map is stable. (2) Fit the hearing aid frequency response for maximal speech intelligibility. (3) Balance the loudness with the cochlear implant and hearing aid. Bimodal fitting can provide optimal use of the different, but potentially complementary, bilateral cues provided by the acoustic amplifier and the electric stimulation from the implant.

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