**Perceptions of Cochlear Implant Audiologists Regarding Sequential Versus Simultaneous Bilateral Cochlear Implants for Children**

Frayne Poeting, BA1  
Donald M. Goldberg, PhD1,2

1College of Wooster  
2Cleveland Clinic Foundation

**Abstract:** This study examined the opinions of cochlear implant audiologists in the United States regarding sequential versus simultaneous bilateral cochlear implants for children. Audiologists were asked about the most important factors they consider when choosing between sequential or simultaneous bilateral cochlear implants for pediatric candidates. All of the responding audiologists valued binaural hearing, but most worked with sequentially implanted patients. For these sequentially implanted recipients, the most common interval between the first and second surgeries was less than one year. Overall, the audiologists were more likely to recommend bilateral sequential cochlear implants to their patients, but many believed that bilateral simultaneous cochlear implants had value. More research is needed to identify the best interval for sequential cochlear implant recipients, along with the need to further investigate the frequency and types of therapy being used for the training of the second ear for these children.

**Key Words:** bilateral cochlear implants, simultaneous cochlear implants, sequential cochlear implants

**Acronyms:** ACIA = American Cochlear Implant Alliance; ANSD = Auditory Neuropathy Spectrum Disorder; CI = cochlear implant

**Correspondence concerning this article should be addressed to:** Donald M. Goldberg, PhD, College of Wooster, 203 Wishart, 1189 Beall Avenue, Wooster, Ohio 44691. Phone: 330-263-2029; Email: dgoldberg@wooster.edu

In our changing landscape for children who are deaf or hard of hearing, some make use of personal hearing aids, but sound may not be adequately amplified to allow for the audibility of the entire speech spectrum. Cochlear implants (CIs) have therefore become an efficacious option, especially for young children (Hammes, Novak, Rotz, Willis, Edmonson, & Thomas, 2002; Vohr, Jodoin-Krauzk, Tucker, Johnson, Topol, & Ahlgren, 2008). There is substantial evidence that children have better listening and language outcomes when they receive early cochlear implantation and participate in early intervention programs (Dornan, Hickson, Murdoch, & Houston, 2007, 2008; Eriks-Brophy, 2004; Eriks-Brophy, Durieux-Smith, Olds, Fitzpatrick, Duquette, & Whittingham, 2006; Fitzpatrick, Rhoades, Dornan, Thomas, & Goldberg, 2012; Hogan, Stokes, White, Tyskiewicz, & Woolgar, 2008; Rhoades, 2001, 2006; Rhoades & Chisholm, 2001; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998).

**Background**

Since the introduction of CIs in the United States for adults in 1985 and for children in 1990, there have been many changes in CI technology and surgical techniques and practices. In the early years, unilateral cochlear implantation was the only option. By the early 2000s, a number of patients had received bilateral CIs in an effort to improve their “ability to localize sound and to understand speech in noise” (Litovsky et al., 2004, p. 648).

Initially there were professionals who questioned the notion that bilateral CIs could surpass “the impressive improvements in perception and linguistic development accrued from monaural implantation” (Papsin & Gordon, 2008, p. 69). But, as evidence has accumulated about the benefits of bilateral CIs, they have become a common treatment for patients with profound hearing loss in both ears (Bichet & Miyamoto, 2008; Scherf et al., 2009). Some patients receive bilateral sequential CIs, in which one ear is fitted with a CI and then several months (or years) later, in a separate surgery, the patient is fitted with a CI in the contralateral ear (Steffens et al., 2008). An even more recent development is bilateral simultaneous cochlear implantation, in which the patient receives CIs in both ears during a single surgery.

Interestingly, in the earliest years of pediatric cochlear implantation, many children did not continue to wear a hearing aid in the contralateral ear. Over time though, more patients became “bimodal” (i.e., one ear had a CI and the contralateral ear was fitted with a hearing aid). A
concern about sequential implantation has been that the ears are not receiving consistent auditory stimulation in tandem and a lag can develop between the function of the ears (and the brain) and that lag can become more pronounced over time (Bichey & Miyamoto, 2008).

Luntz, Shpak, and Weiss (2005) have stated, “there is a natural tendency for the contralateral residual acoustic hearing in CI candidates to diminish, possibly to the point of complete deafness” (p. 863). Another concern when an interval is created by delaying implantation of the second ear is that there may be negative effects on the patient's binaural processing (Gordon, Valero, & Papsin, 2007; Papsin & Gordon, 2008). According to Gordon et al. (2007), most clinicians on CI teams in the United States attempt to minimize the interval between the first and second sequential implants.

With bilateral simultaneous cochlear implant surgery, lag time of auditory stimulation is not an issue. Additional benefits of bilateral hearing include the absence of binaural processing challenges, improved speech perception in noise, the summative effect of two ears, and the feeling of balance (Johnson, 2012).

A host of negatives has also been raised regarding bilateral simultaneous CIs, including: the potential negative sequelae of being under anesthesia for a longer time; possible surgical complications (no longer considered a viable complication, according to Gantz et al., 2002; Grainger, Jonas, & Cochrane, 2012; Ramsden, Papsin, Leung, James, & Gordon, 2009); and negative vestibular side effects (Mick, Friesen, Shipp, & Chen, 2012; Papsin & Gordon, 2008). Additionally, some parents want to “save one ear” in the hope that more advanced technologies, such as stem cells or better hearing technology might become available in the future (Zeitler et al., 2008).

It should also be mentioned that some pediatric patients do not want to be without sound for any period of time. For others, including patients with Auditory Neuropathy Spectrum Disorder (ANSD), some CI team members work to assess the outcomes of implanting a first CI prior to proceeding to a second CI (see Roush, Frymark, Venediktov, & Wang, 2011; Roush, 2011). Therefore, some patients with bilateral ANSD are only initially “approved” for a unilateral CI.

The purpose of this research investigation was to explore the opinions and practices of CI audiologists about sequential or simultaneous bilateral cochlear implants for children.

Method

Audiologists working with pediatric cochlear implant candidates at cochlear implant centers throughout the United States were recruited for participation. The audiologists were contacted by email after using the American Cochlear Implant Alliance (ACIA) institution membership listing along with the “Find a Clinician” search bar for each of the three U.S.-based CI manufacturers. A Territory Manager for Cochlear America also circulated the survey participation request to other managers in the United States.

The electronic, on-line survey was designed to collect information about audiologists’ opinions and practices regarding bilateral cochlear implantation with children. The survey was developed using Qualtrics. A total of 20 questions were set up using Likert-type scales and multiple-choice responses (4 demographic questions and 16 questions about past clinical experiences). A final open-ended question was also included. Prior to any data collection, the research project was reviewed and approved by the Human Subject Research Committee at the College of Wooster.

Results

A total of 57 audiologists responded, although not all of the questions were answered by all of the respondents. All of the respondents held a Master’s degree (6%), a doctorate in Audiology (82%), or PhD or other doctoral degree (13%). Respondents varied in their years of experience: 31% with 6–10 years, 26% having 1–5 years, 20% with 11–15 years, 9% with 16–20 years, and 11% having more than 20 years of experience. Participants came from 21 different states and the most common work site was a hospital-based CI center (reported by 74% of the respondents). The number of pediatric bilateral recipients the audiologists had worked with over the last 12 months ranged from 10 respondents with 1–5 recipients, 13 having seen 6–10 patients, 4 with 11–15 recipients, and 17 who had worked with 16 or more recipients. Most of the patients seen by these audiologists had sequential cochlear implants (73%) and only 27% had simultaneous implants.

The most common interval between cochlear implants for the bilateral sequential patients was quite variable as shown in Figure 1. A total of 73% waited 1–6 months and 23% waited 7–12 months between the first and second implants. The shortest interval reported was 3 months.

The respondents felt that the most important benefits of bilateral hearing for children included localization, the summation effect, better hearing in noise, and reduced listening effort, as shown in Figure 2. Better hearing in noise was noted most frequently followed by reduced listening effort.

When asked why parents reported selecting sequential CIs over simultaneous CIs, the most common reasons...
were concerns about risk to the contralateral ear (21%), parents wanting to save the contralateral ear for future technology (15%), surgeon or physician preference (13%), insurance issues (10%), and the fact that their facility simply did not do simultaneous surgeries (8%; see Figure 3).

Table 1 shows Likert-type scale ratings (with 1 reflecting least important through 7 for most important) about why sequential implants might be preferred over simultaneous implants. The highest rated item was concern about the risk to the contralateral ear (mean rating of 5.1), followed by concern for patients with Auditory Neuropathy Spectrum Disorders (mean rating of 4.1).

As shown in Table 2, the most important factors impacting the decision-making process about whether to do a bilateral simultaneous implantation, included minimal benefit with hearing aids use (mean rating of 6.1) and that the child was profoundly deaf in both ears (mean rating of 6.0).

Respondents were also asked to evaluate the primary disadvantages of sequential versus simultaneous CIs. As seen in Figure 4, the most common disadvantage cited for sequential CIs, was negatively impacts future binaural processing.

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Figure 1. Surgery interval between first and second cochlear implants for bilateral sequential patients.

Figure 2. Audiologists’ opinions about the primary benefits associated with binaural hearing.
Figure 3. Audiologists’ opinions about why parents select sequential implantation over simultaneous implantation.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Least Important</th>
<th>Most Important</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSD (both ears) (n=39)</td>
<td>10.2% (n=4)</td>
<td>17.9% (n=7)</td>
<td>4.10</td>
<td>2.10</td>
</tr>
<tr>
<td>Save contralateral ear (n=39)</td>
<td>17.9% (n=7)</td>
<td>5.1% (n=2)</td>
<td>3.49</td>
<td>1.89</td>
</tr>
<tr>
<td>Risk to contralateral ear (n=39)</td>
<td>0% (n=0)</td>
<td>17.9% (n=7)</td>
<td>5.10</td>
<td>1.68</td>
</tr>
<tr>
<td>Vestibular concerns (n=39)</td>
<td>15.4% (n=6)</td>
<td>10.2% (n=4)</td>
<td>3.13</td>
<td>1.64</td>
</tr>
<tr>
<td>Anesthesia (n=39)</td>
<td>10.2% (n=4)</td>
<td>25.6% (n=10)</td>
<td>3.85</td>
<td>1.77</td>
</tr>
<tr>
<td>Being without hearing (n=39)</td>
<td>7.7% (n=3)</td>
<td>12.5% (n=5)</td>
<td>3.69</td>
<td>1.79</td>
</tr>
</tbody>
</table>

Note. ANSD = Auditory Neuropathy Spectrum Disorder.
Respondents rated how frequently they recommended that their pediatric CI candidates should obtain bilateral sequential CIs, using a Likert-type scale of 1 (never) through 7 (always). The mean rating was 4.5 compared to a mean rating of 4.0 when asked about how frequently they recommended bilateral simultaneous CIs.

Additional questions focused on simultaneous CIs, beginning with a question about why clinicians definitely do not recommend the bilateral simultaneous option. Asymmetrical hearing loss or contralateral ear had acoustically aid-able hearing were cited by 40.5% as the main reasons for not proceeding immediately to simultaneous CIs. Another 18.9% indicated that simultaneous CIs were not recommended when a patient presents with ANSD.

The option of having children wear a hearing aid on the non-implanted ear was almost universally endorsed, with 89.2% of the audiologists responding with yes for their patients going through the sequential route.

A final question asked if there were any questions or concerns not addressed in the survey. Although only 16 participants provided a response, the common theme of 7 audiologists was that they would recommend either bilateral sequential or bilateral simultaneous CIs on a case-by-case basis; and 3 respondents indicated that insurance approval dictates whether sequential or simultaneous implants are done.

**Discussion**

All of the audiologists responding to the survey supported the use of bilateral versus unilateral hearing, with the most important identified value of binaural hearing being improved listening in noise, followed by reduced listening effort. The latter finding supports the work of Hughes and Galvin (2013) who similarly reported on reduced listening effort with binaural hearing.

Although the number of bilateral simultaneous CIs for the pediatric population have increased (Bichey & Miyamoto, 2008; Papsin & Gordon, 2008; Scherf et al., 2009), the majority of audiologists who responded to this survey were seeing and/or recommending more sequential versus simultaneous procedures for bilateral cochlear implants. But, in keeping with the long-held value of truly binaural hearing, the average interval between the patients receiving their first CI and their second CI was under 12 months.

The most frequent explanations for why the majority of the bilateral CI recipients were sequential instead of simultaneous was that many patients had only obtained

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**Table 2**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Least Important</th>
<th>Most Important</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal benefit with hearing aids (n=39)</td>
<td>2.6% (n=1)</td>
<td>7.7% (n=3)</td>
<td>25.6% (n=10)</td>
<td>56.4% (n=22)</td>
</tr>
<tr>
<td>Profoundly deaf (both ears) (n=39)</td>
<td>5.1% (n=2)</td>
<td>2.6% (n=1)</td>
<td>7.7% (n=3)</td>
<td>17.9% (n=7)</td>
</tr>
</tbody>
</table>

**Figure 4.** Primary disadvantages of bilateral sequential cochlear implants.
a unilateral CI when they were younger and now wanted to obtain a second ear. Other frequently mentioned rationales included concerns about the risk to the contralateral ear and its residual hearing, or parents who desired to save the non-implanted contralateral ear for future technological improvements. Additional reasons for the sequential CIs were asymmetrical hearing losses, need for insurance approval, and surgeon preference. Interestingly, a number of sequential recipients presented with ANSD, and the CI team members typically opted for sequential versus simultaneous CI management for these patients (see also Roush et al., 2011).

For those patients who received a unilateral CI, almost all continued to wear a hearing aid on the contralateral ear. This bimodal option presumably ensures that the non-implanted ear still receives some auditory stimulation and the potential for binaural hearing (Luntz et al., 2005). Ultimately, more and more of these bimodal patients, in a fairly short period of time, become bilateral CI candidates, and proceed to having a second cochlear implant so they are able to enjoy the benefits of binaural hearing.

Patients who received bilateral simultaneous CIs, most typically presented with an early diagnosis of a significant hearing loss and then embarked on a hearing aid trial. Other bilateral simultaneous CI recipients had a bilateral profound degree of hearing loss and were demonstrating minimal or no benefit from hearing aids, and soon were approved for CIs for each ear during one surgical procedure.

**Conclusions**

Although the sample for this study was small and may not be representative of all cochlear implant audiologists in the country, it begins to explore some important issues that need to be evaluated by additional research with larger and more representative samples. Four preliminary conclusions can be drawn from this study:

1. All of the audiologists surveyed valued binaural hearing.
2. The majority of these audiologists most often recommended and worked with sequential patients. This finding must be considered with some caution, especially due to changing CI candidacy criteria through the years. Although most of the respondents were treating both bilateral sequential and simultaneous CI recipients, there were those who treated sequential CI recipients exclusively. Despite all the noted benefits of binaural hearing, sequential CIs were still the preferred method of implantation for the respondents to this survey.
3. The most common interval reported for the sequential CI patients was less than a year.
4. There were other outside influences and factors that often eliminated bilateral simultaneous CIs as an option—notably insurance and hospital policies. In addition, some parents continued to report that they were interested in saving the contralateral ear for future technological improvements.

The findings noted above suggest a number of issues that should be investigated further. One important issue is the amount of time between the first and second surgeries in sequential cochlear implants. Future studies should probe this topic with more discrete time frames regarding the interval; so instead of providing only the 1–6 months and 7–12 month interval choices, more options might include smaller interval lengths. In addition, a larger sample size should be strongly considered for future investigations. And finally, future studies should investigate evidence-based practices regarding the therapy options for bilateral simultaneous and sequential cochlear implants (Kuhn-Inacker, Shehata-Dieler, Muller, & Helms, 2004).

As we consider the changing landscape of deafness, the introduction of bilateral CIs appears to be a most important and positive development. If the sky is the limit for children who are deaf and hard of hearing, gaining access to truly binaural hearing will help in their journey to hear from both sides; and in so doing, optimize their speech, language, and auditory outcomes.

**References**


