cochlear implants international, Vol. 11 No. 4, December, 2010, 247–53

Bilateral Cochlear Implants in Long-Term and Short-Term Deafness

Celene McNeill
Healthy Hearing & Balance Care, Australia
William Noble
University of New England, Australia
Suzanne C Purdy
University of Auckland, New Zealand
Anna O'Brien
National Acoustic Laboratories, Australia
Mridula Sharma
Macquarie University, Australia

This is a case study of a 70-year-old man with single-sided deafness (SSD) in the right ear since childhood, who developed a sudden severe hearing loss in the left ear at age 63. Eventually, after he received cochlear implants in both ears, he started to present behavioural auditory processing skills associated with binaural hearing, such as improved ability to understand speech in the presence of background noise, and sound localization. Outcomes were measured using cortical auditory evoked potentials, speech perception in noise, sound-localization tests, and a self-rating questionnaire. The results suggest that even after more than 50 years of unilateral deafness it was possible to develop binaural interaction and sound localization as a result of electric auditory stimulation.

keywords auditory deprivation, bilateral cochlear implant, cortical plasticity, single-sided deafness (SSD), sound localization

History

A male adult presented with a total hearing loss in the right ear since 8 years of age due to mumps. He grew up accustomed to the common problems associated with a

 DOI 10.1179/146701010X486480

single-sided deafness, such as head shadow effects, difficulty understanding speech in noise and inability to localize sounds. He graduated and worked as a pharmacist and was also a keen musician, playing the piano and singing in a choir. In 2001, at the age of 63, he developed a sudden sensorineural hearing loss in his only hearing ear, diagnosed as endolymphatic hydrops. He was fitted with a hearing aid in the left ear, which provided only limited benefit.

This patient's audiological profile was outside CI candidacy guidelines at the time (Dowell et al., 2003). However, six months later he received a cochlear implant in the right ear based on the premise that 'there was nothing to lose'. A Cochlear Nucleus 24-Contour CI was implanted in the right ear and switched on with an Esprit 3G speech processor.

Results of cochlear implant and hearing aid (Bimodal) stimulation

Cortical auditory evoked potentials (CAEP) and open-set speech perception scores were measured in the free-field for three different conditions (left hearing aid alone, right CI alone and bimodal), at 6 and 9 months post implantation of the right ear (Kelly et al., 2005; McNeill et al., 2007).

At 6 months after implantation of the right ear, the responses from the left hearing aid were still dominant as seen in the cortical responses.

The difference in bimodal listening compared to right CI or left hearing aid alone was apparent in the cortical responses at 6 months (Figure 1) and improved at 9 months (Figure 2) after the right CI. This improvement was confirmed by speech tests (Table 1) and patient subjective report.

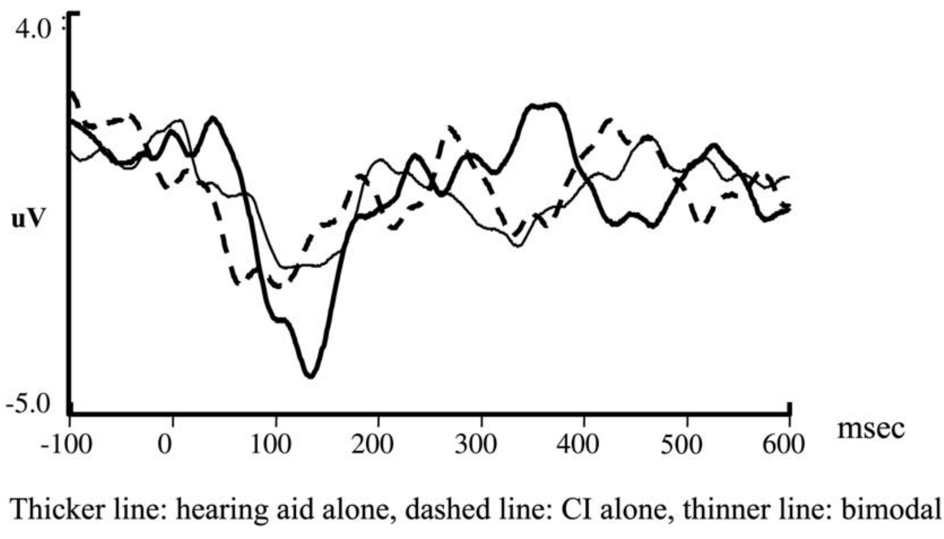

FIGURE 1 Cortical auditory evoked potentials recorded at 6 months after the right CI measured at Cz-A1 (vertex to left ear lobe reference) using a 4 kHz tonal stimulus at a comfortable listening level presented in the free field.

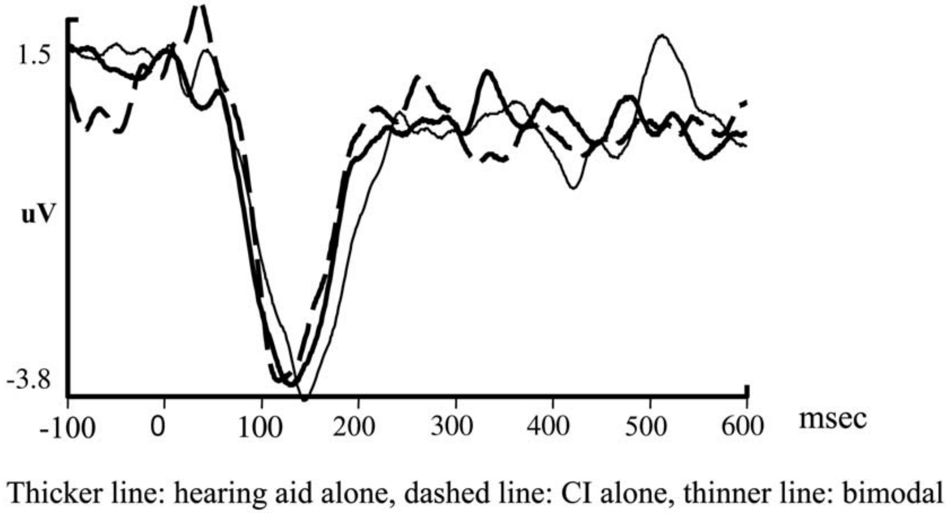

FIGURE 2 Cortical auditory evoked potentials measured 9 months after the right CI, measured at Cz-A1 (vertex to left ear lobe reference) using a 4 kHz tonal stimulus at a comfortable listening level presented in the free field.

TABLE 1

SPEECH SCORES MEASURED AT 6 MONTHS AND 9 MONTHS AFTER THE RIGHT CI USING OPEN-SET SENTENCES PRESENTED AT 65 DB SPL IN THE FREE FIELD

	H/Aid Left (%)	C.I. Right (%)	H/aid + C.I. (Bimodal) (%)
Six months post right CI	7 (CUNY)	66	47
Nine months post right CI	9 (CUNY)	58	87

These results show evidence of a binaural interaction effect, with different responses in the bimodal condition than with either device alone, in spite of long-term deafness in the right ear (McNeill et al., 2007).

Decision to implant the second ear

Eighteen months postoperatively the patient reported great satisfaction with the right implant. He was using bimodal stimulation (CI in the right ear and hearing aid in the left ear) but was relying mostly on the CI. He was back at work and reporting significant improvement in his hearing ability.

In 2005, after three years of bimodal hearing, the left ear continued to deteriorate and the hearing aid was no longer useful. Bilateral implantation was then considered (Litovski et al., 2004) and the left ear was subsequently implanted with a Cochlear Nucleus Freedom CI. At this stage the right speech processor had also been upgraded to a Cochlear Freedom device.

Results with bilateral implants

1. Speech perception in noise

Twelve months after receiving the second implant, the patient scored 90% with bilateral CI for open-set sentences (BKB/A) presented at 65 dB SPL in babble noise at +10 dB signal-to-noise ratio.

2. Cortical responses

Cortical auditory evoked potentials with bilateral implants was attempted but waveforms resulted in a large artefact so that it was not possible to objectively determine whether a cortical response was present (McNeill et al., 2009). While further research is undertaken regarding the use of CAEP with bilateral CI, performance and subjective measures were relied on to assess the outcomes for this patient.

3. Sound localization

Twelve months after binaural implantation the patient noticed an ability to identify where sounds were coming from, for the first time since he could remember. This
1 ability was consistent with other studies of patients with bilateral implants (Van Hoesel and Tyler, 2003).

In order to confirm subjective report, localization tests were then performed in an anechoic chamber using a circular array (1.7 m radius) of 20 loudspeakers at 18° intervals in the horizontal plane using speech signals at 65 dB SPL. The patient sat in the centre of the array with his interaural axis aligned with the loudspeakers at 90° and 270° azimuth, and was asked to identify the loudspeaker from where each of the 40 randomly presented signals were perceived.

Figures 3a–c show scatter plots of the source-response in relation to the speech signal for three different conditions.

4. Self-Rating Questionnaire

The Speech, Spatial and Qualities of Hearing scale (SSQ) devised by Gatehouse & Noble in 2004 and the SSQ(B), which is still in its experimental stage, were used. The SSQ assesses ability in three areas: speech hearing, spatial hearing, and other qualities of hearing, on a scale of 1(none at all) to 10 (perfect). The SSQ(B) measures benefit in the same three areas as a consequence of intervention (in this case, the second CI), by rating each item on a scoring ruler −5 (much worse), 0 (unchanged) to +5 (much better).

Questionnaire results are displayed in Table 2. There was a strong contrast in Spatial and certain Qualities ratings between the patient and the control case of single sided deafness. In the latter case Spatial hearing is rated as non-existent, but naturalness and identifiability are rated very highly. These contrasts suggest substantial benefit for spatial hearing provided by bilateral implantation, whilst also indicating the loss of quality that flows from artificial hearing. Our patient also reported a noticeable reduction in quality and identifiability of sounds since becoming reliant solely on electric stimulation and was aware of the 'livelier' quality of what he hears on the left side, which was more recently normal.

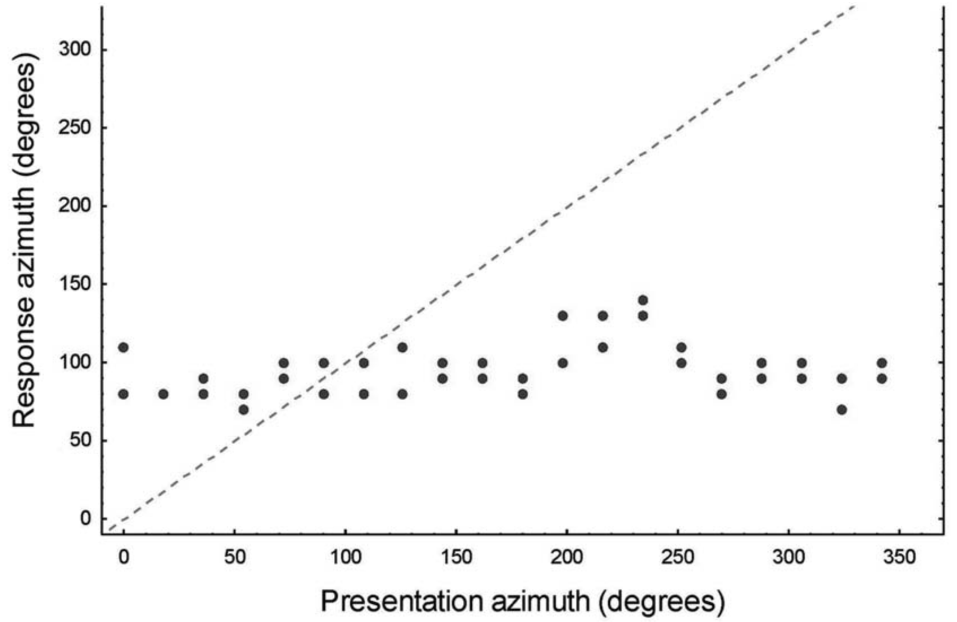

FIGURE 3A Sound localization results with the CI in the right ear only, with responses located around the rightward (90°) loudspeaker. Perfect localization would result in points along the diagonal line.

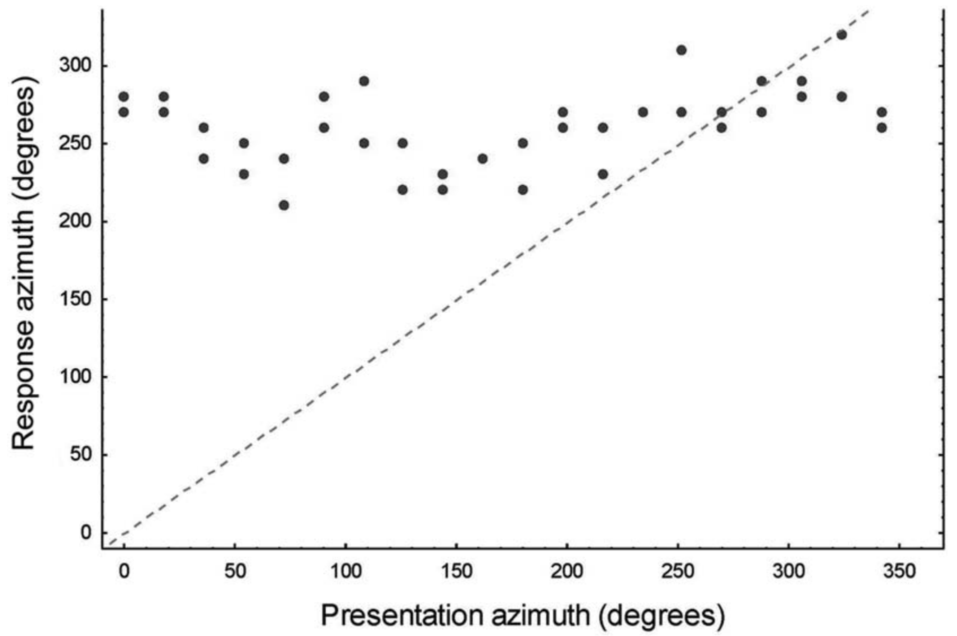

FIGURE 3B Sound localization results with the CI in the left ear only, with responses located from around the left side (270°) loudspeaker. Perfect localization would result in points along the diagonal line.

ONLINE COLOUR ONLY

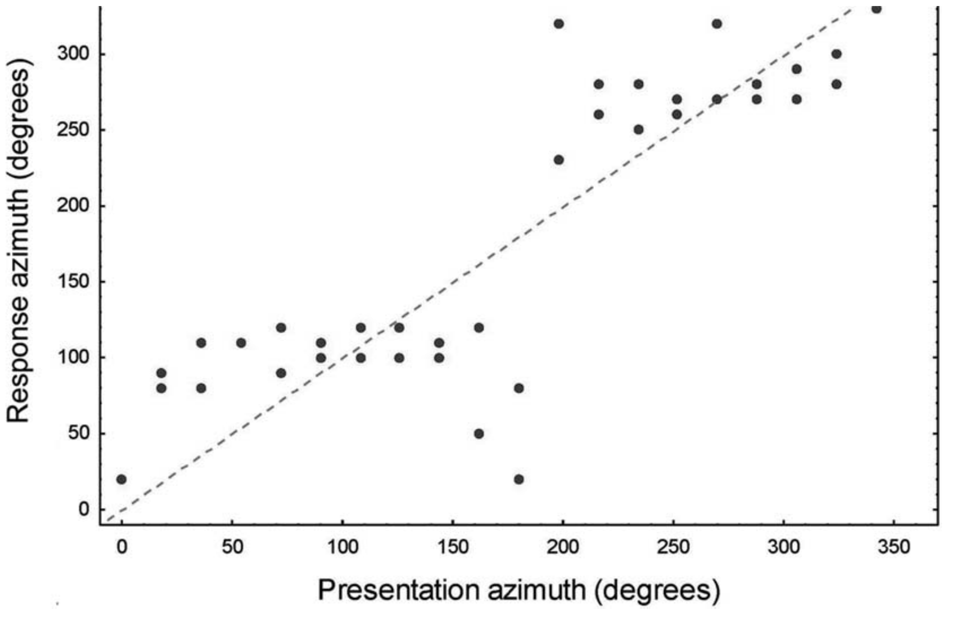

FIGURE 3C Sound localization results with bilateral CI, with all signals correctly located and no errors across the midline. Note the improvement in localization compared to one CI alone.

TABLE 2

PATIENT'S SELF-RATINGS ON SSQ SUBSCALES COMPARED TO ONE SUBJECT WITH RIGHT SINGLE SIDED DEAFNESS (SSD) AND WITH THE AVERAGE RESPONSES OF 36 SUBJECTS WITH BILATERAL CI USED AS CONTROLS. STANDARD DEVIATIONS ARE SHOWN IN PARENTHESES FOR THE CONTROL GROUP DATA. THE LAST COLUMN SHOWS PATIENTS RESPONSES TO SSQ(B)

SSQ Subscales	Patient (n = 1)	Control subject with right SSD (n = 1)	Control group average responses (n = 36)	Patient's benefit scores (n = 1)
Speech				
Speech in quiet	9.5	7.5	8.1 (1.3)	+5.0
Speech in noise	6.5	6.0	5.7 (1.9)	+4.0
Speech in speech contexts	8.3	8.3	5.3 (2.2)	+3.8
Multiple speech-stream processing and switching	6.0	4.2	4.1 (2.2)	+2.0
Spatial				
Localization	7.2	0	5.8 (2.3)	+4.2
Distance and movement	6.8	0.5	5.7 (1.9)	+3.6
Quality				
Sound quality and naturalness	5.8	9.4	6.9 (2.0)	+4.0
Identification of sound and objects	5.6	9.4	6.6 (2.1)	+3.6
Segregation of sounds	8.7	2.7	6.0 (2.2)	+4.3
Listening effort	5.0	2.0	6.1 (1.8)	+4.0

Conclusion

The data demonstrate that the patient is functioning almost at a normal hearing level at listening to speech in background noise and is able to reliably localize speech to the left or right hemisphere in the horizontal plane. This highly proficient performance is echoed in his self-ratings. It can also be assumed, from the CAEP observations in his earlier (bimodal) profile, that the bilateral CI condition is enabling binaural auditory processing to occur.

However, an important consideration in this case is that the right and left ear deafness, despite very different onsets, were both postlingually acquired. The right total hearing loss was acquired at age 8 and the left at age 63. This means that his auditory pathways would have had fully developed in his first 8 years of life. Outcomes might have been different if the profound hearing loss had been of a pre-natal cause in any of the two ears. As demonstrated by previous study (Pelizzone et al., 1991), bilateral CI provided different cortical responses when the right ear had a congenital hearing loss and the left was acquired.

This case study shows that the access to bilateral auditory information, despite degraded signal quality as provided by electrical stimulation, can enable cortical plasticity to take place and auditory processing skills to reconfigure in acquired deafness, regardless of advanced age and length of previous auditory deprivation.

References

Dowell, R., Hollow, R. & Winton, L. 2003. Changing Selection Criteria for Cochlear Implants — the Melbourne Experience. Cochlear N95506 ISSI.

Gatehouse, S. & Noble, W. 2004. The Speech, Spatial and Qualities of Hearing Scale (SSQ). *International Journal of Audiology*, 43(1): 85–99.

Kelly, A.S., Purdy, S.C. & Thorne, P.R. 2005. Electrophysiological and Speech Perception Measures of Auditory Processing in Experienced Adult Cochlear Implant Users. *Clinical Neurophysiology*, 116: 1235–246.

Litovsky, R.Y., Parkinson, A., Arcaroli, J., Peters, R., Lake, J. & Johnstone, P. et al., 2004. Bilateral Cochlear Implants in Adults and Children. *Archives of Otolaryngology, Head and Neck Surgery*, 130: 648–55.

McNeill, C., Sharma, M., Purdy, S.C. & Agung, K. 2007. Cortical Auditory Evoked Responses from an Implanted Ear after 50 Years of Profound Unilateral Deafness. *Cochlear Implants International*, 8(4): 189–99.

McNeill, C., Sharma, M. & Purdy, S.C. 2009. Are Cortical Auditory Evoked Potentials Useful in the Clinical Assessment of Adults with Cochlear Implants? *Cochlear Implants International*, 10: 78–84.

Pelizzone, M., Kasper, A., Hari, R., Karhu, J. & Montandon, P. 1991. Bilateral Electrical Stimulation of a Congenitally-Deaf Ear and an Acquired-Deaf Ear. *Acta Otolaryngologica (Stockh)*, 111: 261–68.

van Hoesel, R.J. & Tyler, R.S. 2003. Speech Perception, Localization, and Lateralization with Bilateral Cochlear Implants. *Journal of the Acoustical Society of America*, 113(3): 1617–30.

2

Notes on contributors

Correspondence to: Celene McNeill, Healthy Hearing & Balance Care, 1204/1 Newland Street, Bondi Junction NSW, Australia 2022. Email: cmcneill@tpg.com.au

Author Query

Journal title: CIM
Volume and issue: 11-4
Article title: Bilateral Cochlear Implants in Long-Term and Short-Term Deafness
Author name: Celene Mcneill *et al*.

QUERY NO.	QUERY DETAILS
1	In the references this is spelled with a lower-case 'v'. Which is correct? (In other words, does this author follow the Dutch system or the Flemish/Afrikaans system?)
2	Author query. I think this needs more detail so that readers can find it. It appears to be on the Internet at http://www.cochlearacademy.com/pdf/Dowell_N95506.pdf so I suggest we refer to that. Would that be acceptable?