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Are cortical auditory evoked potentials useful in the clinical assessment of adults with cochlear implants?

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ABSTRACT *Cochlear implant (CI) trends are changing as more recipients are receiving bilateral implantation. Also more pre-lingually deafened adults are choosing to be implanted. Clinical assessment after cochlear implantation is usually based on speech perception tests. Such tests, however, may not be a realistic outcome measure for some of these cases, creating a need for more objective measures of CI performance. Cortical auditory evoked potentials (CAEPs) recorded in the sound field may be a fast and reliable procedure for the clinical audiologist to determine CI outcomes. This paper presents two case studies illustrating CAEP findings in an adult CI user who was pre-lingually deafened and a bilateral CI user.*

Keywords: cortical; cochlear implant; artefact; auditory evoked potentials; pre-lingual

Introduction

Bilateral cochlear implantation is a growing trend. In Australia, there also seems to be an increasing number of pre-lingually deaf adults choosing cochlear implantation rather than a new hearing aid at the time that their old instruments need replacement. The reason may be that, in this country, children receive free audiological services including provision of hearing aids, batteries and repairs from government clinics. Adults aged over 21 lose eligibility for this free service and hence they need to purchase their own hearing aids privately. Private health funds only reimburse around 20 per cent of the cost of a hearing aid, while cochlear implants (CIs) attract a 100 per cent rebate. This economic factor may be playing a significant role in the decision making process for CI candidates.

Adults with pre-lingual deafness receiving and/or seeking cochlear implantation are required to have a consistent history of amplification but typically rely on vision as their primary mode of communication (i.e. sign and/or speech reading). CI candidates are more likely to succeed if there is a previous history of consistent hearing aid usage (Klop et al., 2007; Santarelli et al., 2008). The goal of cochlear implantation for this group of clients may be sound awareness rather than open set speech recognition, however, a recent study showed steady improvements in speech perception with reasonably good speech recognition scores three years after implantation in a group of adult CI users who were pre-lingually deafened, aged 20 years on average at implantation (Santarelli et al., 2008).

Speech perception tests are usually the clinical tool of choice when assessing performance with a CI. Speech testing can be problematic for adults who are prelinguistically deafened, if speech perception and production skills are limited. Since subjective speech perception tests may not be a reliable measure of CI benefit for some individuals, it would be useful to have an objective indicator of auditory function with a CI. A number of studies have used cortical auditory evoked potentials (CAEPs) to objectively assess auditory function with a CI in children and adults (e.g. Kelly et al., 2005; McNeill et al., 2007; Oviatt and Kileny, 1991; Ponton et al., 1996). In adults with normal hearing CAEPs consist of three main peaks occurring at around 50, 100 and 200 ms, respectively, referred to as P1-N1-P2, but in younger children the response is dominated by a large positive peak referred to as P1 (Wunderlich and Cone-Wesson, 2006). The current paper describes CAEP recordings in two adult CI users.

Case 1

Case 1 is a 65 year old female (referred to here as Anita) with a congenital profound sensorineural hearing loss in both ears due to maternal rubella. She reported using hearing aids in the left ear since childhood until 30 years of age when she started wearing hearing aids in both her ears. She had been a regular bilateral aid user until she received an implant in the right ear three years ago, at the age of 62. Anita's mode of communication has been mainly oral with the aid of speech reading. Pre-operative aided speech scores using audition alone for the right ear were 20 per cent, while the left ear scores were 40 per cent. Current criteria for cochlear implantations of adults include aided speech recognition scores worse than 70 per cent in the better ear (Dowell et al., 2003). Anita met this criterion and was implanted with a CI Medel Combi 40+ with Tempo Speech Processor in

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Table 1: Anita's unaided and aided hearing thresholds and speech perception scores (per cent correct), three years after CI switch-on

	Unaided	CI Right ear	HA Left ear	Bimodal
500 Hz	75 dB HL	20 dB HL	30 dB HL	20 dB HL
1000 Hz	90 dB HL	25 dB HL	30 dB HL	25 dB HL
2000 Hz	NR > 90 dB	25 dB HL	40 dB HL	25 dB HL
4000 Hz	NR > 90 dB	20 dB HL	NR	20 dB HL
6000 Hz	NR > 90 dB	25 dB HL	NR	25 dB HL
/ba/ stimulus	75 dB nHL	25 dB nHL	25 dB nHL	25 dB nHL
Speech in quiet (BKB/A sentences at 65 dB SPL)	0%	10%	46%	48%
Speech in noise (BKB/A sentences at 65 dB SPL in babble noise)	0%	10%	30%	30%

CI = Cochlear implant; HA = hearing aid; BKB/A = Bamford Kowal Bench/Australian version.

the right ear. She continued to use a Phonak Super Front PPC L4 high power hearing aid in the left. Two years after switch-on it was still difficult to establish a reliable map as Anita's behavioural responses were very inconsistent. It appeared that she was still relying on her left hearing aid and speech reading for communication, although she maintained that, subjectively, the CI had significantly improved her hearing ability. Table 1 shows hearing thresholds unaided, for separate ears with the CI only, hearing aid only and bimodally. Speech perception was tested using Bamford Kowal Bench/Australian version (BKB/A) sentences presented at 65 dB SPL from a front loudspeaker at 1 m. Speech in noise was tested using babble noise presented via a loudspeaker behind the listener, at 1 m distance, with a signal to noise ratio of +10 dB.

Case 2

The second client is a 68 year old male (Mathew) who acquired a profound sensorineural hearing loss in the right ear at eight years of age due to mumps. The left ear was affected by hydrops later in life. The right ear was implanted first with a Cochlear Nucleus 24 Contour with an Esprit 3G speech processor after more than 50 years of unilateral profound deafness. Mathew's CAEPs have been reported previously (McNeill et al., 2007). The left ear was implanted two years later with a Cochlear Nucleus Freedom as his hearing progressively worsened to the point that the left hearing aid was no longer useful. The right speech processor was subsequently upgraded to a Freedom device so that he now wears bilateral Freedom speech processors. Mathew is doing extremely well with bilateral implants. Twelve months after the second implant he scores 90 per cent with bilateral implants for BKB/A sentences presented at 65 dB SPL in babble noise at +10 dB signal to noise ratio.

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CAEPs

The Intelligent Hearing System evoked potential equipment was used to measure CAEPs unaided, CI alone, hearing aid alone and bimodally. A 115 ms /ba/ stimulus was used, with 750 ms inter-stimulus interval. Stimuli presented in the sound field from the front loudspeaker at 1 m distance, at 60 dB nHL.

Case 1's CAEPs were recorded with the non-inverting electrode located at the vertex (Cz), the inverting electrode on the earlobe contralateral to the CI and the ground electrode on the forehead (Figure 1). The unaided trace is noisy, which illustrates one of the problems with CAEP response identification. In order to be confident that an evoked response is present, waveforms should be replicated, usually with 50–100 averages per waveform for CAEP recordings. The left ear aided response shows peaks with latencies and morphology consistent with a normal P1-N1 and P2 pattern. The bimodal recording appears to be dominated by the CI

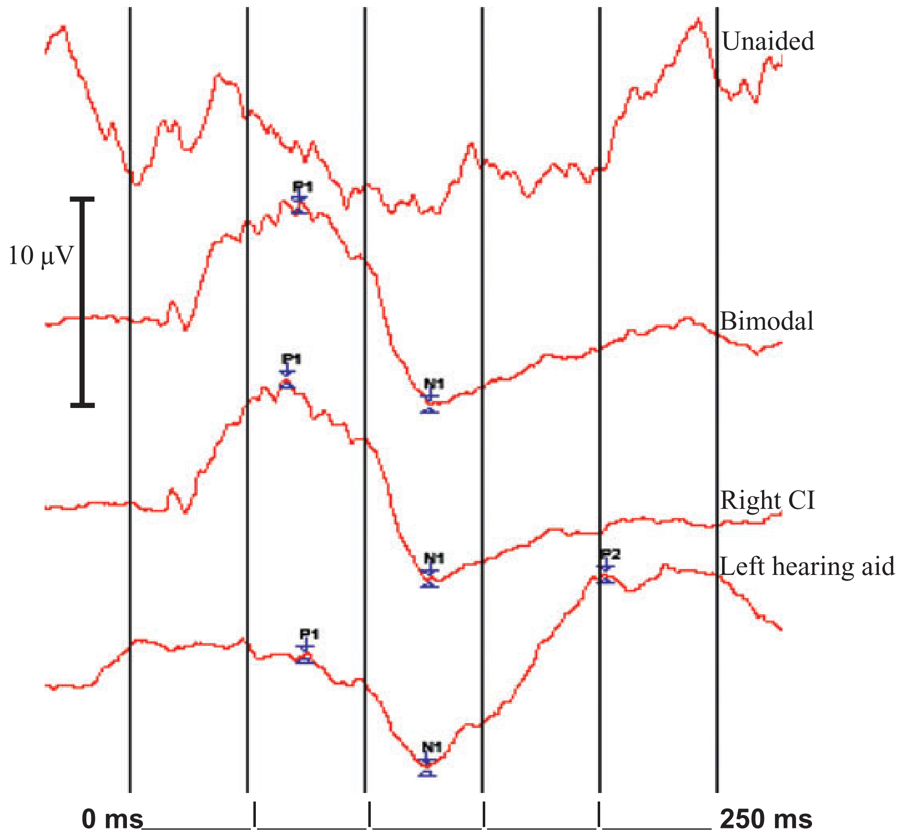

Figure 1: Case 1's cortical auditory evoked potential (CAEP) waveforms. The CAEP amplitudes are measured between the peak and following trough. For the bimodal condition, the CAEP amplitude is 9.8 μV. CI = Cochlear implant.

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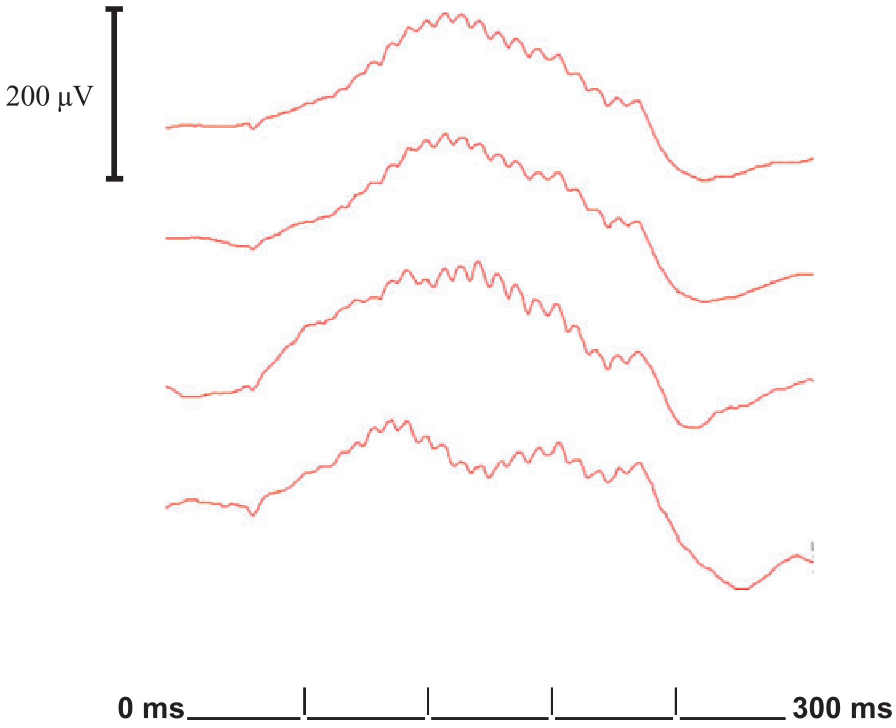

Figure 2: Case 2's cortical auditory evoked potential (CAEP) waveforms recorded with bilateral cochlear implant stimulation. No CAEP peaks are evident due to the large electrical artefact (266.4 μV) obscuring the waveform.

response. Anita's CAEPs have an immature response morphology, similar to waveforms recorded in young infants (e.g. Kurtzberg, 1989), consisting of a broad, large amplitude positive peak at several hundred milliseconds after the stimulus. This is consistent with her pre-lingual deafness.

Case 2's CAEP waveforms recorded with two CIs activated are shown in Figure 2. The waveform contains a large artefact and it is not possible to determine whether a cortical response is present, illustrating one of the problems of CAEP recordings in bilateral CI.

Summary and conclusions

Based on our clinical experience, CAEPs have the potential to be a fast and reliable tool for CI assessment. There are, however, some limitations that need to be overcome in order for CAEPs to be more clinically useful. Firstly, more data are needed to establish the link between CAEP latencies and amplitudes and speech perception abilities. There is considerable published normative CAEP data

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(Wunderlich and Cone-Wesson, 2006). Normative data can be used to determine whether the CAEP waveform is age-appropriate, and whether implantation results in a more mature response. This information will be useful when monitoring Case 1's progress with her CI.

A second limitation illustrated with Case 2 is the electrical artefact that occurs in some CI CAEP recordings. The artefact is often present in the region where the early CAEP peaks should be (Gilley et al., 2006). The artefact occurs when the speech processor is activated and lasts at least as long as the duration of the stimulus (Gilley et al., 2006). Distribution of the artefact on the scalp varies according to the type of CI and mode of stimulation. Although artefact can occur with unilateral CIs, it is more prominent with bilateral stimulation. One strategy to reduce artefact is to place the non-inverting electrode on the ear opposite the CI (Sharma et al., 2002). This solution does not work for CAEPs recorded with bilateral implant stimulation, as illustrated in Figure 2. Gilley et al. (2006) and Martin (2007) discussed a statistical technique such as independent component analysis to separate artefact from CAEPs, but this approach is not available with current clinical evoked potential instruments. Further work is needed to develop clinical solutions for reducing the electrical artefact that contaminates CAEP recordings with bilateral CI stimulation.

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