International Journal of Pediatric Otorhinolaryngology 79 (2015) 2028–2034

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

# Speech processing in children with cochlear implant

Takwa A. Gabr [a,*], Mohammad R. Hassaan [b]

[a] Associate Professor of Audiology, Audiology Unit, ENT Department, Faculty of Medicine Tanta University, Tanta, Egypt
[b] Associate Professor of Audiology, Audiology Unit, ENT Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

ARTICLE INFO

*Article history:*
Received 1 June 2015
Received in revised form 29 August 2015
Accepted 1 September 2015
Available online 11 September 2015

*Keywords:*
Cochlear implants
Speech processing
Speech-evoked ABR (SABR)
Cortical auditory evoked potentials (CAEPs)

ABSTRACT

Cochlear implants (CIs) can be used effectively in the profoundly impaired children individuals.

*Objectives:* This work was designed to assess speech processing at brainstem and cortical level in children fitted with CIs to investigate the possible influence of brainstem processing of speech on the cortical processing in those children.

*Method:* Twenty children fitted with CIs underwent aided sound-field audiologic evaluation, speech evoked cortical auditory evoked potentials (S-CAEPs) and according to the results, children were classified into two groups: group I with good cortical response and group II with poor cortical response. This was followed by speech evoked ABR (S-ABR) recoding.

*Results:* P1 component of CAEPs was recorded in all children while other component showed variable results. S-ABR was recorded in all children even those with poor S-CAEPs response who showed delayed D, E, F and O latencies. However, S-ABR amplitudes did not show any significant difference between both groups.

*Conclusions:* Children fitted with CI showed immediate cortical activation following device programming and this activity depends on the age of implantation as well as the child's age. S-ABR provides a new clinical tool that showed an important role of brainstem in complex sound processing that contribute to cortical processing.



## 1. Introduction

Cochlear implants (CIs) are devices designed to use electric stimulation of the remaining auditory nerve fibers for hearing restoration in the profoundly impaired individuals [1]. Unlike a hearing aid, the use of CI allows for damaged inner ear by-pass, permitting direct stimulation of the auditory nerve fibers [2]. Cochlear implants represent one of the most important achievements of modern medicine, as for the first time in history an electronic device is able to restore a lost hearing sense [3].

Prelingually deaf children develop significant speech perception and production abilities over time as the use of CIs radically improves deaf children's access to spoken language and the intelligibility of their speech [4]. These achievements may appear limited in the first two years, but show significant improvement after the second year of implantation, and do not reach a plateau, even 5 years following implantation [5,6]. However, children with CIs show deficits in language abilities compared to hearing children, at least in the first years following implantation [7,8].

The verification of CI benefit in very young population is a challenging process owing to the absence of spoken language and the subject's feedback. Results regarding the acquisition of spoken language in children with profound deafness fitted with CI are astonishing. It is a crucial element of rehabilitation process that follows the surgical implantation [9].

Auditory brainstem response (ABR) provides such an objective measure for evaluation of hearing thresholds in infants, children, and in difficult to test individuals [10]. Traditionally, the ABR has used short, simple stimuli, such as pure tones and tone bursts. Recently, ABR has also been recorded to complex sounds such as speech and termed as complex ABR (c-ABR) and it provides an objective measure of subcortical speech processing [11]. Complex ABR arises largely from the inferior colliculus of the upper midbrain [12] functioning as part of a circuit that interacts with cognitive, top-down influences. Unlike the click-evoked ABR, the c-ABR waveform is remarkably similar to its complex stimulus

* Corresponding author at: ENT Department, Tanta University Hospitals, El-Geesh Street, Tanta 31725, Egypt. Tel.: +2 0100 13 23 962; fax: +2 040 333545.
*E-mail address:* takwagabr@gmail.com (T.A. Gabr).

http://dx.doi.org/10.1016/j.ijporl.2015.09.002

waveform, allowing for fine-grained evaluations of timing, pitch, and timbre representation [13].

The use of aided auditory evoked potentials (AEPs) for assessment of amplification benefit has got much attention in the past decade because of its objectivity and applicability in young age population [14]. Specifically, the use of CAEPs has an advantage due to its cortical origin giving an idea about the function of higher auditory centers [15]. Moreover, the use of speech stimuli to evoke the cortical potentials can predict the speech perception in young amplification users who don't fit for psychophysical tests [16]. Researchers has linked the efficiency of cortical responses in terms of their latencies, amplitudes [17] and number of produced waves [18] with speech recognition scores of HAs or CI users.

In new CI users, particularly those with delayed neural maturation, these potentials may not be produced [19]. Complex-ABR represents a lower neural response with earlier maturational course than the cortical response [20] which may provide information about the amplification benefit in young age CI patients. This relatively earlier course of maturation may minimize the factors affecting its reproducibility in young ages and may gain the advantage of predicting speech capabilities [21].

## 2. Aim of the work

In this study we hypothesized that recording of S-ABR in CI users can be used as a predictor for speech processing at cortical level. We used speech syllables for c-ABR recording. So, we referred to complex ABR as Speech-ABR (S-ABR). This work was designed to evaluate and compare S-ABR and S-CAEPs recordings in CI children aiming to investigate the possible influence of brainstem processing of speech on the cortical processing in those children.

## 3. Subjects and methods

We recruited twenty children (2–6 years) fitted with unilateral CIs for this study. They were chosen from children attending the Audiology Units at Tanta University Hospitals. Consents were taken from parents of children after explaining the test procedures and this study has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). All the children had pre-or peri-lingual onset of severe to profound sensorineural hearing loss and received their implants at ages ranging from 2 to 6 years. The etiology of hearing loss was heredo-familial in ten patients (with positive family history), post-febrile in two patients and idiopathic in the rest of patients.

Inclusion criteria: children with bilateral severe to profound hearing loss SNHL that was not successfully treated with optimal hearing aid fittings for at least 6 months were included in this study. The exclusion criteria included: un-cooperative children including those with mental retardation, developmental or behavioral disorders, irregularity in HA use before CI surgery or improper rehabilitation therapy.

Children of this group met the selection criteria for CI: bilateral severe to profound hearing loss as shown from results of sound field or play audiometry, absent ABR and absent otoacoustic emissions, normal IQ, normal EEG activity, normal appearance of cochlea and auditory nerve as evidenced by CT scan and MRI and unsatisfactory aided response after proper binaural HAs fitting for at least 6 months before deciding to proceed into CI surgery. After CI surgery and programming, Soundfield testing using CIs were done warable tones and speech materials. Good aided response is obtained when the aided response is $\leq$30 dBHL along the frequency range of 250–4000 Hz.

The types of CIs were: Sonata Opus 2 processor in 10 patients (MED-EL), freedom processor (Cochlear) in 5 patients and harmony processor (Advance Bionic) in 5 patients. As regard side of implantation, 9 patients received CI in their right ears and 11 patients received CI in their left ear. Children of this work were subjected to the following:

### 3.1. Aided sound field

Children were seated in the sound proof room positioned one meter away from and at 45° angle to right and left loudspeakers two loud-speakers. The child was asked to indicate whenever he/she heard the warble tones till reaching the aided threshold. The test was done at 500, 1000, 2000 and 4000 Hz as well as speech reception threshold (SRT) with very simple monosyllabic words or digits or speech detection threshold (SDT) according to the child's vocabulary.

### 3.2. Aided click-evoked ABR

Click-evoked ABR was recorded using Smart-Evoked potentials system of Intelligent Hearing System (IHS). Recording start at 70 dBHL to confirm the presence of wave V using repetition rate (RR) of 19.3/s and time window of 0–12 ms. After recording a response at 70 dBHL, the intensity was reduced in 10 dB steps till reaching the aided threshold to confirm satisfactory aided sound field results particularly in young children.

After 1–2 months of regular use of CI at a stable map with reliable and satisfactory aided sound field and aided ABR results, children were enrolled in the rehabilitation program. At the start of the rehabilitation program, the following procedures were done for all children.

### 3.3. Speech-evoked CAEPs (S-CAEPs)

CAEPs were recorded in response to CV syllables/da/of 206 ms duration presented at 70 dBHL and 0.5/s RR. The filter setting was 1–30 Hz with alternating polarity, 0–450 ms time window and the total number of sweeps was 30. Three averages were recorded and the responses were considered to be present if components of S-CAEPs were identified in at least 2 out of the 3 averages.

### 3.4. Speech-evoked ABR (S-ABR)

Speech-ABR was recorded using the same CV speech stimulus that was used for S-CAEPs (speech syllable/da/) which was presented at 70 dBHL, 11.1/s RR and time window of 0–75 ms. As in S-CAEPs recording, three averages were recorded and the responses were considered to be present if components of S-ABR were identified in at least 2 out of the 3 averages.

For both types of ABR recording, the filter setting was 150–1500 Hz with alternating polarity and the total number of sweeps was 1024. Both types of stimuli (click and/da/) used for recoding ABR and CAEPs, they were presented delivered via loudspeaker at 45° azimuth angle according to the implanted side and at distance of 50 cm. For each evoked potential test, three blocks of 1024 artifact free sweeps were collected for each tested ear. Four disposable electrodes were fixed according to the Smart-EP manual specification as the following: one high frontal Fz (positive electrode), one low frontal Fpz (ground electrode). The last two electrodes were placed on the left and right mastoids (as negative electrode or reference electrode) depending on the recording side.

### 3.5. Response analysis of S-ABR

Click-ABR was obtained in each ear before recording S-ABR to confirm the presence of wave V as mentioned before. For S-ABR, the response was identified by the presence of seven waves (V, A, C,