International Journal of Pediatric Otorhinolaryngology 79 (2015) 660–665

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

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

Effect of cochlear implant electrode array design on auditory nerve and behavioral response in children

Laila M. Telmesani [a], Nithreen M. Said [b,c,*]

[a] Otology & Neuro-Otology, Otorhinolaryngology Department, Faculty of Medicine, Dammam University, Dammam, Saudi Arabia
[b] Audiology Unit, Otorhinolaryngology Department, Faculty of Medicine, Dammam University, Dammam, Saudi Arabia
[c] Audiology Unit, Otorhinolaryngology Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt

A R T I C L E I N F O

Article history:
Received 7 January 2015
Accepted 5 February 2015
Available online 14 February 2015

Keywords:
Electric compound action potential
ECAP
Neural response telemetry
Cochlear implant electrodes
Objective assessment

A B S T R A C T

Aim: To study the effect of change in the array design of cochlear implant electrode on electrophysiological, and behavioral functional measures of cochlear implant users.
Method: A total of 33 children using cochlear implants were included in this study. Subjects were implanted with different electrode types including Slim Straight (CI422) and Freedom Contour Advance (CI24RE) electrode arrays. The electrically evoked compound action potential (ECAP) thresholds were evoked by stimulation of basal, mid, and apical electrodes. The behavioral aided responses using the implant were obtained about 6–12 months post fitting of implant.
Results: ECAP thresholds decreased significantly postoperatively in both electrode arrays. Slim straight electrode (CI422) had higher thresholds than Freedom Contour Advance (CI24RE) electrode at most recording sites, but the differences were only significant at basal site. This is a direct consequence of a perimodiolar electrode versus a lateral wall electrode, i.e., the neurons are further away requiring more current (higher threshold) to record the NRT.
Conclusion: Although the curved electrode array appeared to evoke responses at lower thresholds, effect on patient performance was not obvious.

1. Introduction

Multichannel cochlear implants have been highly successful in restoring speech understanding in individuals with severe-to-profound hearing loss. Most individuals are able to obtain postoperative improvement in word recognition scores with cochlear implants [1].

One factor that may limit performance after cochlear implantation is the broad spread of electrical current within the cochlea, which may result in greater channel interaction, higher current needs, and less opportunity to take advantage of newer speech processing strategies [2].

One way to improve patient performance is to manipulate the anatomical placement of the electrode array within the scala tympani of the cochlea. Various cochlear implant manufacturers have concentrated on changing the electrode design to direct the contacts toward the modiolus and place the electrode array in a peri-modiolar position [3].

To achieve medial placement, Cochlear Limited (Sydney, Australia) uses a pre-curved electrode array, the Nucleus freedom Contour advance (CI24RE). Many studies have reported that the peri-modiolar position decreases threshold levels, increases dynamic range and improves spatial selectivity of neural activation [4–9]. These changes could contribute to more effective channels within the implant system, which may improve the understanding of speech in both quiet and noisy listening situations [9–11].

Another way of improving the performance of cochlear implants is to increase the likelihood and degree of preservation of hearing through improved surgical techniques and technological developments [1]. Even though the perimodiolar electrode allows significant preservation of residual hearing, its greater volume and stiffness produces a higher degree of residual hearing loss as a result of the possibility of mechanical trauma [1].

The Nucleus Slim Straight cochlear implant (CI422) which was recently developed by Skarzynski et al. [1] together with Cochlear Ltd., Sydney, Australia, has an electrode array with a total length of 25 mm, and smaller dimensions than the Nucleus Contour Advance electrode arrays (diameter 0.3–0.6 vs. 0.5–0.8 mm).

* Corresponding author at: Ain Shams University, Audiology-Otorhinolaryngology, Cairo, Egypt. Tel.: +00201002500123.
E-mail addresses: nithreens@yahoo.com, nithreen@gmail.com (N.M. Said).

http://dx.doi.org/10.1016/j.ijporl.2015.02.008
0165-5876/

Being half-banded, it provides a 'smooth' side which may reduce trauma when it is moved along the lateral wall of the scala. CI422 is an improvement on the existing full-banded Nucleus Straight array both in terms of insertion trauma and the potential to conserve residual hearing.

Electrophysiological recordings of the auditory system such as the electrically evoked compound action potential (ECAP) provide useful objective measures of neural response to auditory stimulation [12,13]. A system of measuring the ECAP, first developed by Cochlear Corporation for the Nucleus 24 device (CI24), is known as neural response telemetry (NRT). Researchers and clinicians have investigated the feasibility of using the ECAP threshold to objectively predict psychophysical measurements and facilitate the programming of the speech processor [14]. Consequently, it is important to determine whether electrophysiological responses in children change with different designs of cochlear implant electrode arrays as these are sometimes the only measures available to set cochlear implant stimulation levels especially in young children or individuals who are difficult to test.

Saunders et al. [4] studied the radial distance of the electrode from the modiolus and concluded that ECAP thresholds and impedance levels would be lower for electrodes closer to the modiolus as a lower current would be needed to stimulate neurons that are in close proximity to an electrode. Gordin et al. [14] reported lower ECAP levels for the perimodiolar 24RE device compared with the older straight electrode 24 M device. Very few studies have compared different generations of electrode arrays and non have compared the slim straight electrode (CI422) to previous generations. In the present study, we were specifically interested in comparing the ECAP thresholds evoked by the recent slim straight (CI422) electrode with those evoked by Freedom contour advance (CI24RE) electrode.

2. Methodology

2.1. Subjects

Thirty-three children were included in the study. All subjects received Nucleus 24 cochlear implant system at King Fahad University Hospital—Dammam University. They had used hearing aids for at least three months prior to cochlear implant surgery and had received auditory verbal rehabilitation. The age at implantation ranged from 1.2 to 5 years old. Subjects were classified into two groups according to the type of implanted electrode array. Group (A) was implanted with Nucleus Freedom Contour Advance array (CI24RE) and group (B) with the Nucleus Slim Straight electrode array (CI422).

2.2. Procedure

All patients were operated on by the same surgeon (the first author). Trans-mastoid posterior tympanotomy approach was used. CI24RE electrode was introduced in group A via a cochleostomy while slim straight electrode (CI422) was introduced in group B via round window.

Electrode impedance and auditory nerve response measures were recorded in the operating room immediately after the cochlear implantation and at the time of fitting. Cochlear Corporation's Custom sound EP software version 3.2 was used for the recording. The Neural response telemetry (AutoNRT) feature was used to record the ECAP.

2.2.1. Intraoperative recordings

Measurements were done in the operating room after the insertion of the electrode into the cochlea and during the closing of the incision. The processor and coil were placed in a sterile camera sleeve, and the transmitter coil was placed over the skin. Impedance levels were measured after which the measurement of ECAP thresholds were done. A fast stimulation rate of 250 Hz was used for ECAP recording to reduce test time in the operating room. Threshold search begins with a relatively high current level.

2.2.2. Postoperative recordings

A speech processor was fitted 4 weeks after surgery. Programming was based on objective ECAP thresholds in the first sessions till behavioral programming levels could be achieved. A slow-rate (80 Hz) was used to record ECAP thresholds. The current stimulation levels begin at low levels to prevent overstimulation and ensure that the patient is comfortable [15]

For intra and postoperative ECAP recordings, biphasic electrical current pulses, 25 μs pulse width, were used to stimulate the electrodes. The amplifier gain ranged from 40 to 60 dB, and recording delays were 50 to 125 ks. AutoNRT "searches" for threshold by presenting a series of ascending and descending current levels. Threshold is defined as the mean of the lowest positive response measurement and the highest negative response measurement [15]. Thresholds from apical (typically no. 22), mid (typically nos. 16 and 11), and basal (typically nos. 6 and 1) sites were selected and analyzed in the study.

Impedance was measured using the standard clinical method for recording impedance in the Custom sound software. Monopolar 1 + 2 mode electrode impedances were analyzed. Electrode impedance levels were measured intra-operatively and at the beginning of the fitting session before ECAP measurement. A decrease in impedance levels was observed after the beginning of electrical stimulation and the use of the device. Measurement of impedance levels was repeated 1 month after the device was fitted and these levels were used to compare the two groups postoperatively.

2.2.3. Hearing evaluation

Regular follow-up assessment was done for the patient every three months after fitting. Aided sound field with the cochlear implant was tested using two channel audiometer model AC40. Aided threshold levels were achieved in a sound treated room using warble tones at zero degree azimuths at a distance of one meter from the loudspeaker at the frequencies (250–8000 Hz). Best aided responses after setting the proper map were presented in the study. At the time of the study, most of our subjects had recently had implants (within the first year) so their language abilities did not allow for an assessment of speech perception.

2.2.4. Data analysis

Statistical analysis was done using the SPSS statistical software program. Simple descriptive analysis was performed in order to calculate arithmetic mean, standard deviation and range. Data were expressed as means and standard deviation for quantitative measures, and as a number for qualitative data. Multi-variant analysis of variances (MANOVA) and t test were used for comparison. Comparative statistics were performed either by Student's t-test (t value) for normally distributed two-independent samples or Mann–Whitney U test (Z value) for nonparametric distribution. P-values less than 0.05 were considered significant, while at 0.01 or 0.001 were highly significant.

3. Results

Table 1 shows demographic data of both study groups comprising 15 males and 18 females. Age at implantation ranged between 1.2 and 5 years old and the subjects had used hearing aids for at least 3 months before implantation. Fig. 1 shows gender distribution of both study groups. The most common