Correlation between NRT measurement and behavioural levels in patients with the Nucleus 24 cochlear implant

Correlazione tra NRT e livelli comportamentali in pazienti portatori di impianto cocleare Nucleus 24

W. DI NARDO, S. IPPOLITO, N. QUARANTA, G. CADONI, J. GALLI
Department of Otorhinolaringology, "A. Gemelli" Hospital, Sacro Cuore Catholic University, Rome, Italy

Key words

Cochlear implant • Neural response telemetry • Behavioural measures

Parole chiave

Impianto cocleare • Neural response telemetry • Misure comportamentali

Summary

Aim of this study was to determine the relationship between the electrically evoked whole nerve action potential (EAP) and T-and C-level for subjects using the Nucleus 24 cochlear implant system. EAP thresholds were measured using the Neural Response Telemetry system of the Nucleus 24 device. Twelve Nucleus 24 cochlear implant users took part in this study. EAP thresholds were compared with the behavioural measures of T- and C-levels used to programme the speech processor. The EAP and the T-and C-levels were obtained, on the same day, 1 month after cochlear implant activation. EAP thresholds were seen to fall between the T- and C-level. On average, EAP thresholds fell at 72% of the map dynamic range. The majority of absent answers were found in three of the 12 patients, and out of a total of 195 activated electrodes an EAP was recorded in 169. These data show that Neural Response Telemetry is a valuable clinical tool in the Nucleus cochlear implant system, providing information concerning integrity of the implant and status of the peripheral auditory nerves.

Riassunto

Lo scopo di questo studio è stato di valutare la relazione esistente tra i potenziali d'azione del nervo ed il livello -T e -C in soggetti portatori di impianto cocleare Nucleus 24. Le soglie dei potenziali d'azione evocati del nervo sono state misurate utilizzando il sistema "Neural Response Telemetry" in dotazione al Nucleus 24. Per questo studio sono stati valutati 12 pazienti impiantati con Nucleus 24. Le soglie dei potenziali d'azione del nervo sono state confrontate con le misure comportamentali dei livelli -C e -T, utilizzate per programmare lo "speech processor". Le misurazioni sono state eseguite lo stesso giorno ed un mese dopo l'attivazione dell'impianto cocleare. Si è osservato che le soglie dei potenziali d'azione evocati del nervo cadevano tra i livelli -T e -C. In media le soglie dei potenziali d'azione evocati del nervo si localizzavano al 72% del range della mappa dinamica. La maggior parte delle risposte assenti sono state riscontrate in 3 dei 12 pazienti, e su un totale di 195 elettrodi attivi, un potenziale d'azione evocato del nervo è stato registrato in 169. In conclusione, questi dati suggeriscono che il sistema "Neural Response Telemetry" è un utile strumento dell'impianto coclerare Nucleus, in quanto è in grado di fornire informazioni riguardanti l'integrità dell'impianto e le condizioni dei nervi uditivi periferici,

Introduction

One of the still unsolved problems in the regulation of cochlear implant parameters concerns the objective definition of T- (Threshold) and C- (Comfort) levels.

Various tools have been proposed for an objective study of the neural response: electrical stapedius muscle reflexes (ESR) and the electrically evoked auditory brain stem response (EABR) [1].

More recently, the evoked auditory action potential (EAP) has been measured in patients using the Nucleus 24 cochlear implant. This device is equipped with a Neural Response Telemetry (NRT) system [2].

NRT is a quick and non-invasive way of recording the EAP of the peripheral auditory nerve in situ by means of the intracochlear electrodes [3-5].

The NRT system works by sending an electrical signal to any selected intracochlear electrode. When this stimulus is large enough to elicit a synchronous neural response, the EAP is recorded from an adjacent electrode, amplified, encoded and transmitted back, via radio frequency, to a Sprint speech processor and displayed on a computer [6 7].

A number of clinical trials have been carried out to study the correlation between the neural response threshold and the behavioural levels used for cochlear implant programming processes but results have not been unanimous [8-10].

Aim of the present study is to examine the relation-

Table I. Characteristics of patients population.

Patient ID number	Sex	Age (yrs)	Auditory deprivation (yrs)	Age of deafness	Active electrodes	Aetiology of deafness
IC 24-1	F	5	0	Pre-lingual	20	Unknown
IC 24-2	M	16	2	Pre-lingual	20	Unknown
IC 24-3	F	27	3	Pre-lingual	20	Unknown
IC 24-4	F	27	2	Pre-lingual	20	Unknown
IC 24-5	M	30	3	Pre-lingual	20	Unknown
IC 24-6	F	33	5	Pre-lingual	20	Unknown
IC 24-7	M	36	3	Post-lingual	20	Méniere
IC 24-8	F	40	6	Post-lingual	20	Meningitis
IC 24-9	M	32	3	Pre-lingual	20	Unknown
IC 24-10	F	2	0	Pre-lingual	20	Unknown
IC 24-11	M	3	0	Pre-lingual	19	Syndromic
IC 24-12	M	18	0	Pre-lingual	16	Unknown

ship between the EAP and the T- and C-levels in subjects implanted with a Nucleus 24 device.

Materials and Methods

A total of 12 patients (6 males and 6 females) aged between 3 and 40 years (mean 22.4) took part in the study. All patients were implanted with a Nucleus 24 device and were fitted with the Sprint speech processor at approximately 1 month after implantation. Details of the study population are summarised in Table I. Mean time of auditory deprivation was 3.1 years (range 6 months-6 years). Ten subjects were prelingually and two postlingually deaf. Out of a total of 240 electrodes, 195 were activated. Maps were created by the cochlear implant audiologist, for each patient, before EAP recording, using the Cochlear Corporation's WinDPS software (Nucleus R126). All Map data presented here were created using SPEAK and ACE processing strategies.

EAP thresholds for 195 electrodes were determined using Cochlear Corporation's software NRT 3.0. The "current level" used both in the NRT software and the WinDPS software are represented in programming units (PU) that vary from 1 to 255 and span a nominal range of approximately 10 μA to 1.75 mA.

The procedures for stimulation and recording of the EAP were:

- monopolar stimulation at a rate of 80 Hz
- masker advance fixed at 500 μs, which is the time between the masker and probe impulse
- amplifier gain set at 60 dB
- sampling delay set at 60 μs.

Responses were typically collected using 50 sweeps at higher, and 100 at lower stimulation levels. When EAP amplitudes were very small, the number of sweeps was increased to 200. EAP threshold was defined as the lowest intensity that elicited a clear response.

In each case, stimulating and recording parameters were adjusted to minimise the effects of the stimulus artefact and to achieve the best response waveform. Typically, if a response was contaminated by the stimulus artefact, the sampling delay was increased from 60 to 100 μs.

All data presented here were obtained in linear regression analysis and statistical significance was set at $p<0.05$.

Results

It was possible to record a good EAP response in 169 (86%) out of a total of 195 activated electrodes. Of the negative recordings, 75% were found in 3 out of the 12 examined patients. Figure 1 depicts the relationship between EAP threshold and T- and C-levels for each electrode. The dark solid line represents the point at which EAP thresholds and C-level equalise C-level (top panel) and T-level (bottom panel). EAP thresholds were localised in 99% of cases above the T-level and below the C-level.

The EAP threshold was found to be more strictly correlated to the T-level ($r=0.616$, $p<0.05$) than to the C-level ($r=0.721$, $p<0.05$) and fell at 53% of the dynamic range of the map in children and at 91% in adults. Mean EAP threshold across electrodes corresponded to 187 and 185 programming units (PU), in children and adults, respectively.

Sample waveforms from two subjects, collected on electrodes 17 from subject IC24-9 and on electrode 5 from subject IC24-6, are shown in Figure 2. In the

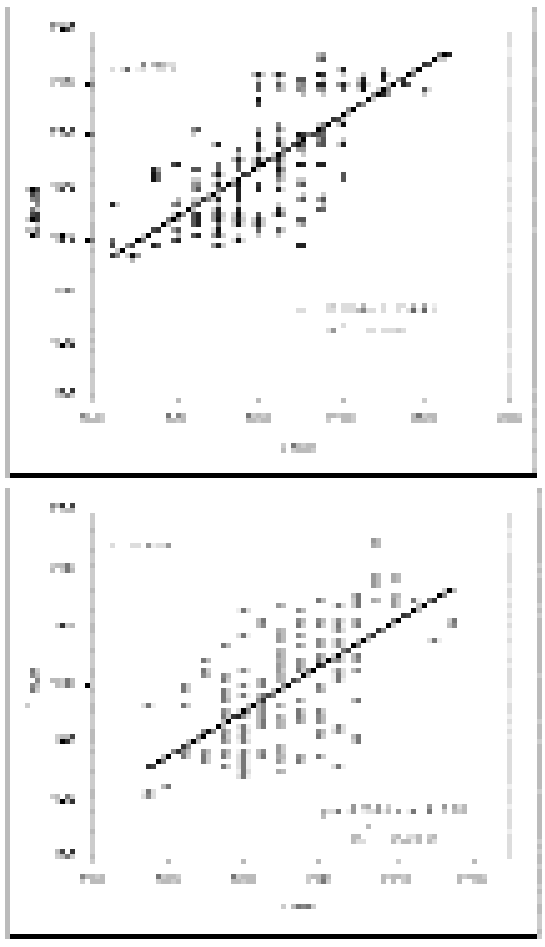

Fig. 1. Top panel: scatter plot of C-level vs EAP threshold (EAP-T) in each of 12 subjects. Bottom panel: scatter plot of T-level vs EAP threshold for same subjects. EAP threshold and MAP levels are all represented in programming units.

first subject (IC24-9), it was not possible to obtain a measurable response, while in the second (IC24-6), the response amplitude decreased with the stimulus intensity level.

Discussion

Availability of an NRT system in the Nucleus 24 cochlear implant allows an easy and rapid electrophysiological estimate to be made of auditory sensitivity.

As a measure of the neural response to electrical stimulation, EAP has several advantages over EABR. First of all, it provides a direct measure of the audi-

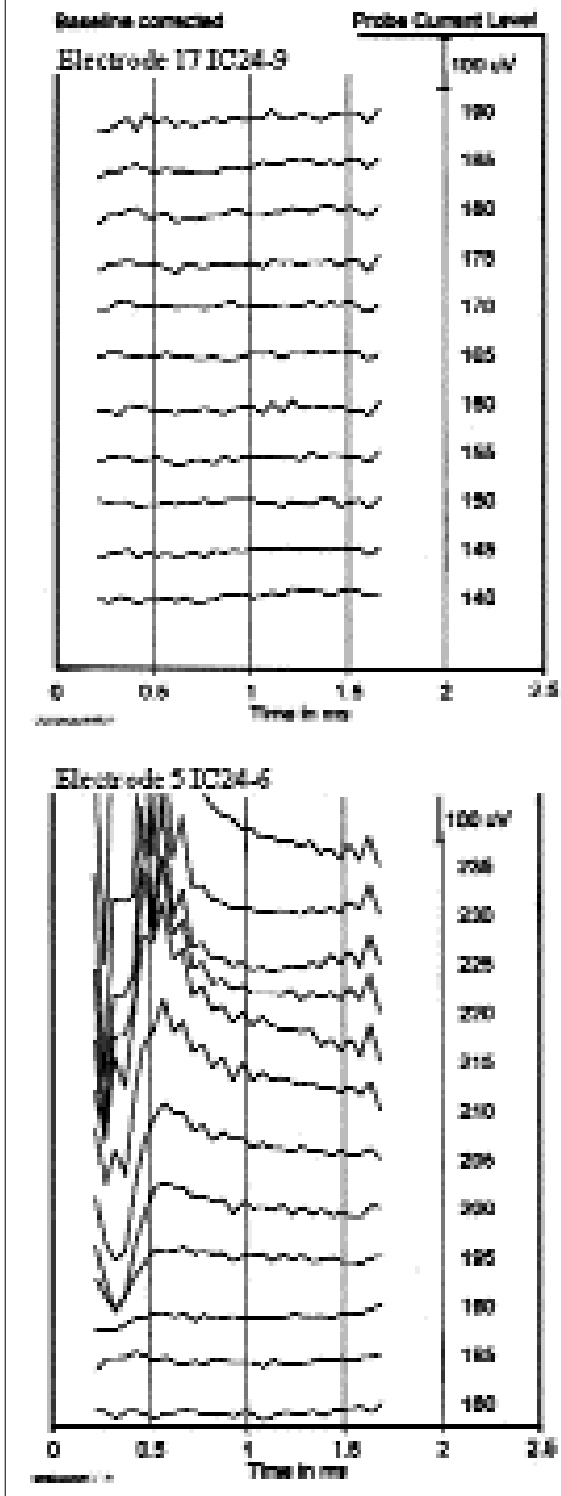

Fig. 2. EAP recordings of electrode 17 from subject IC24-9 and 5 from subject IC24-6. Stimulus level in PU is labelled in each waveform.

tory nerve function; second, no surface recording electrodes are needed; third, the potential is measured from inside the cochlea and, therefore, neither sleep nor sedation are necessary. Furthermore, fewer sweeps are required due to a decreased contamination by muscle artefacts, thus reducing test duration.
The present findings are in agreement with those by Hughes et al. [4] who demonstrated that EAP thresholds show a significant correlation with T- and C-levels.
The trend seen in EAP thresholds across electrodes both in adults and children are similar to those seen for T- and C-levels. Even if EAP thresholds fell closer to the T-level, in some subjects, or closer to the C-level, in others, they were almost always (99.3%) within the subject's dynamic range across all electrodes.
Mean EAP threshold was 187 PU in children and 185 PU in adults, these values dropped at 53% of the map's dynamic range in children and at 91% in adults. As reported by other Authors [1], this slight difference is probably due to the fact that children have higher map T- and C-levels than adults. In our study, mean C-levels in children were higher (208 PU) than in adults (189 PU) leading to a larger dynamic range of the map.
Our data suggest a close correlation between EAP thresholds with both T- and C-levels.
As we were unable to record EAP in only 3 patients, it is tempting to hypothesise that a dysfunction of the peripheral auditory nerve was present in these cases.
According to data in the literature, the best method to predict T- and C-levels is to use EAP thresholds in conjunction with behavioural responses on one electrode [11 12].
Brown et al. [11 12] demonstrated that EAP thresholds showed a relatively small variability across adjacent electrodes and tended to follow contours of the map. They developed a formula to predict the map level based on the EAP thresholds for all the electrodes and the map levels for one electrode.
Since it is often difficult to obtain reliable behavioural responses in very young children, NRT may be used to define the maps based upon EAP thresholds rather than arbitrarily setting a T- or C-level. Thus, the EAP thresholds can provide an indication of "safe" levels of stimulation. Further research is needed in order to determine stricter correlation between NRT and T- and C-level, to confirm the present data and to find an adequate explanation for the rare cases (< 4%) in which NRT responses are absent at the highest stimulation levels.

References

1 Thai-Van H, Chanal JM, Coudert C, Veuillet E, Truy E, Collet L. *Relationship between NRT measurements and behavioral levels in children with the Nucleus 24 cochlear implant may change over time: preliminary report.* Int J Pediatric Otorhinolaryngol 2001;58:153-62.

2 Brown CJ. *Relationship between NRT and Behavioural Threshold and Comfort Levels.* European Custom Sound Outcomes Seminar, Sintra, June, 1999.

3 Brown CJ, Hughes ML, Lipez S M, Abbas PJ. *The relationship between EABR thresholds and levels used to program the Clarion speech processor.* Ann Otol Rhinol Laryngol (Suppl.) 1999;177:50-7.

4 Hughes ML, Brown CJ, Abbas PJ, Wolaver AA, Gervais JP. *Comparison of EAP threshold with MAP levels in the Nucleus 24 cochlear implant: data from children.* Ear Hear 2000;21:164-74.

5 Szyfter W, Pruszewics A, Karlik M, Swidzinski P. *First experiences in Neural Response Telemetry in patient with Nucleus 24 cochlear implant system.* Otolaryngol Pol 2000;54:337-42.

6 Abbas PJ, Brown CJ, Hughes ML, Gants BJ, Wolaver AA, Gervais JP, et al. *Electrically evoked compound action potentials recorded from subjects who use the Nucleus C124M device.* Ann Otol Rhinol Laryngol 2000;185(Suppl.):6-9.

7 Brown CJ, Abbas PJ, Borland J, Bertschy MR. *Electrically evoked whole nerve action potentials in Ineraid cochlear implant users: responses to different stimulating electrode configuration and comparison to psychological responses.* J Speech Hear Res 1996;39:453-67.

8 Abbas PJ, Brown CJ, Shallop JK, Firszt JB, Hughes ML. *Summary of results using the nucleus C124M implant to record the electrically evoked compound action potential.* Ear Hear 1999;20:45-59.

9 Dillier N, Lai WK, Almqvist B, Frohne C, Muller-Deile J, Stecker M, et al. *Measurement of the electrically evoked compound action potential via a neural response telemetry system.* Ann Otol Rhinol Laryngol 2002;111:407-14.

10 Miller CA, Abbas PJ, Brown CJ. *An improved method of reducing stimulus artefact in the electrically evoked whole-nerve potential.* Ear Hear 2000;21:280-90.

11 Brown CJ, Abbas PJ, Gantz BJ. *Preliminary experiences with neural response telemetry in the Nucleus C124M cochlear implant.* Am J Otol 1998;19:320-7.

12 Brown CJ, Hughes ML, Luk B, Abbas PJ, Wolaver AA, Gervais P. *The relationship between EAP and EABR thresholds and levels used to program the nucleus 24 speech processor: data from adults.* Ear Hear 2000;21:151-63.

Received: 10 February 2003
Accepted: 29 April 2003

■ Address for correspondence: Dr. W. Di Nardo, Istituto di Otorinolaringoiatria, Policlinico "A. Gemelli", L.go A. Gemelli 8, 00168 Roma, Italy. Fax: +39 06 3051343.