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Excitation characteristic of a bipolar stimulus for broadband stimulation in measurements of electrically evoked auditory potentials

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Abstract

Objective: *The aim of this study was to determine the optimum electrical stimulation mode for the measurement of electrically evoked potentials. To quantify the broadband excitation electrically evoked compound action potentials were recorded in cochlear implant recipients. The full width half maximum was determined for spread of excitation along the electrode array.*

Design: *Prospective clinical study.*

Study sample: *The study sample consisted of 20 adult cochlear implant users.*

Results: *The applied alternating, intracochlear stimulation mode leads to neural excitation along approximately 80% of the length of the electrode array. The median of the full width at half maximum values covered the range of 18 electrodes on the implant array.*

Conclusion: *The bipolar, alternating, and intracochlear stimulation mode would provide a sufficient, broadband excitation of the spiral ganglion to measure electrically evoked auditory potentials.*

Anregungscharakteristik eines bipolaren Stimulus zur breitbandigen Reizung bei Messungen elektrisch evozierter auditorischer Potentiale

Zusammenfassung

Ziele: *Das Ziel dieser Studie war die Ermittlung eines geeigneten elektrischen Stimulationsmodus zur Messung elektrisch evozierter Potentiale. Um die Anregungsbreite des elektrischen Stimulus zu bestimmen wurden elektrisch evozierte Summenaktionspotentiale an Cochlea-Implantat-Patienten gemessen. Zur Bestimmung der Anregungsbreite über den Elektrodenträger wurde die Halbwertsbreite bestimmt.*

Design: *Prospektive klinische Studie.*

Studiengrösse: *In die Studie wurden 20 erwachsene Cochlea-Implantat-Patienten eingeschlossen.*

Ergebnisse: *Der verwendete alternierende, intracochleäre Stimulus ermöglicht eine breite Anregung des Spiralganglion von etwa 80% des*

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gesamten Elektrodenträgers. Der Median der Halbwertsbreite erfasst 18 Elektroden des implantierten Elektrodenträgers.

Zusammenfassung: *Bipolare, alternierende und intracochleäre Stimulation kann eine ausreichend breite Anregung des Spiralganglion zur Messung elektrisch evozierter Potentiale erzeugen.*

Keywords: Cochlear implant, Evoked compound action potential, Electrical evoked auditory brainstem response, Diagnostic

Schlüsselwörter: Cochlea-Implantat, Evozierte Summenaktionspotentiale, Elektrisch evozierte Hirnstammpotentiale, Diagnostik

Introduction

Cochlear implantation has become an established therapy for the treatment of severe to profound hearing loss, but the outcome differs considerably between patients. There are several different influences, and combinations thereof that contribute to the great variability in auditory performance of cochlea-implant (CI)-recipients [1,2]. Besides factors such as duration of hearing loss, age of deafness, and implantation one must account for changing patient etiology. The broadening selection criteria accept patients who have types of hearing loss or comorbidities that may limit the recipients' auditory performance [3–5]. Therefore, an urgent need for objective, electrophysiological methods for differential diagnostic of the auditory periphery exists. Most of the objective measures currently applied intra- and postoperatively in CI-patients are conducted to support the postoperative fitting of CI systems. Rather than diagnostic, the main target of these measures is the electrode function or overall estimation of the electrical hearing threshold or comfort level [6–8].

In the field of cochlear implantation, where non-acoustic stimuli are applied to evoke and record evoked potential responses, several objective techniques are in use. The electrically evoked compound action potential (ECAP) is the whole-nerve action potential generated by the most distal auditory nerve fibers. Intraoperative ECAP recording via the CI therefore contribute to the assessment of device function and allows the surgeon to immediately confirm the correct placement of the cochlear implant electrode [9]. The potential benefit of utilizing ECAP measurements has been suggested by several authors [10–12]. In the case of CI recipients with unexpected poor outcomes or decreasing performance during the course of treatment, a diagnostic tool is needed as well to determine the potential root cause [12]. Furthermore, based on objective measures, these recipients may benefit from an individually tailored and specialized therapy.

Along with the measurement of electrical evoked auditory brainstem responses being commonly used as an objective estimator for stimulation levels [6,13], electrical evoked middle latency potentials have been described as a reliable method to determine the electrophysiological threshold [14]. The electrically evoked cortical potentials also have proven to be a valuable postoperative tool in diagnostics and research; i.e. for monitoring neuroplastic changes after cochlear implantation [15]. These objective measures require different excitation characteristics of the eliciting signal dependent upon the diagnostic questions. In example the use of acoustic click stimuli for broadband excitation of the cochlea is a well-established method routinely used for differential diagnostics of the auditory pathway [16]. Hence a broadband stimulus is a crucial method [17] for the elicitation of electrically evoked auditory potentials (EAP).

The aim of this study is to provide a broadband, click-equivalent electrical stimulation to the cochlea. For this purpose, we propose the use of a bipolar, alternating, and intracochlear stimulation mode for the elicitation of EAP. To determine the bandwidth of the electrical stimulation we measured the excitation of the cochlea by means of ECAP recordings following a bipolar stimulation.

Material and methods

Subjects

This prospective study included 20 CI recipients, who were implanted with a Nucleus device (CI24RE(CA), CI422 or CI512). All were postlingually deafened adults with a mean age of 54.4 years ranging from 24 to 80. Apart from having no comorbidities, the main inclusion criterion was open speech recognition, defined as a minimum speech reception score in Freiburg Monosyllables of more than 50% at 65 dBSPL presentation level with frontal sound incidence in free field. This criterion serves to exclude CI-recipients with apparent restricting factors for speech understanding, e.g. deprivation of auditory nerve. The group mean experience was 21.4 month, the individual experiences ranged from 2 month up to 62 month at the time of speech recognition assessment.