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Intra-operative test electrode and electrical auditory brainstem response after pre-operative assessment in cochlear implant candidacy

Comparison of electrical auditory brainstem response results by using an auditory nerve test electrode and system intra-operatively after an pre-operatively objective promontory stimulation test to check integrity of the patient’s auditory pathway

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Abstract: Introduction: Over the last years, in doubt of cochlear implant (CI) candidacy, assessment of excitability of the auditory nerve is performed with pre-operative tests. These tests are the pre-operative (pre-op.) performed electrical auditory brainstem (EABR) and the late response (EALR) recorded with trans-tympanic promontory stimulation in local anesthesia. But in some cases after such preoperative tests there is still doubt about the excitability of the auditory pathway. The most reliable EABR is recorded with using stimulation via the CI. However, before CI implantation, an intra-cochlear test electrode could be used in order to achieve similar EABR results. Methods: In doubtful cases of patients who underwent pre-op. EABR, we performed EABR by a test electrode, part of the auditory nerve test system. This measurement was used to confirm the pre-operative results just before CI implantation. Additionally, EABR using CI stimulation was performed intra-operatively right after the CI implantation to confirm EABR using the test stimulation electrode results. Results: Six subjects were included in this study. They were tested by pre-op. EABR (n=6), pre-op. EALR (n=5), intra-op. EABR using test electrode (n=6), intra-op. EABR via CI (n=6), and post-op. EABR (n=2), and post-op. EALR (n=2). In two cases, intra-operative EABR showed a positive, i.e. clearly measureable, response whereas there was a doubtful response in pre-op. EABR. Intra-op. EABRs (test electrode and CI stimulation) showed the same results in all cases. Waveforms of EABR using test electrode look similar to EABR using CI stimulation but with more defined peaks compare to the pre-op. EABR. In one case with all-over positive EABR, pre-op. EALR, and post-operative EALR were matching. Conclusion: Intra-op. EABR using test electrode was easy to record and it shows similar results to EABR using CI stimulation. Intra-op. EABR using test electrode may help in confirming the results of not clear pre-op. EABR with a minimal increase in recording time.

Keywords: intra-cochlear, test electrode, promontory stimulation, electrical stimulation, electrical auditory brainstem response, trans-tympanic, cochlear implant, auditory nerve.

1 Introduction

In doubtful candidacy of cochlear implant (= CI) patients, electrical auditory brainstem response (EABR) is a useful tool to evaluate the integrity of the auditory pathway when standard evaluation [1] failed to clarify the auditory status.
In earlier publications [2, 3] trans-tympanic electrically evoked auditory brainstem response measurement in local anesthesia (pre-op. EABR) has been reported as one option for such a scenario. In the last years, also cortical analysis has been reported to be possible by trans-tympanic electrically evoked auditory late response measurement in local anesthesia (pre-op. EALR) [4]. These two measurements allow for the analysis of different areas along the auditory pathway.

However such tests may not work in all cases, due to subject movements, being awake in local anesthesia, which add noise to the recording, and due to not effective and precise stimulation, being done with a transtympanic electrode on the round window area.

Previous works showed that a test electrode can be used intra-operatively to test electrically the auditory nerve by EABR recording, similar to a CI, but with the advantages to have an external re-usable stimulator [5]. intra-op. EABR using test electrode correlates very well with EABR using CI stimulation in normal CI candidates and subject undergoing tumor removal [6].

The goal to this study is to include in the test chain the intra-operative EABR in general anesthesia, using a test electrode just before CI implantation, and EABR from the implanted CI post-operatively, comparing the EABR results between pre-operative, intra-operative and post-operative sessions.

2 Methods

Patients selected for pre-operative auditory pathway evaluation by electrical stimulation using pre-op. EABR and pre-op. EALR went through standard audiological tests. These patients were uncertain CI candidates due to the doubt presence or excitability of the auditory nerve.

The detailed methods of pre-op. EABR and pre-op. EALR can be found in previous publications [3; 4].

In contrast to the pre-operative EABR and EALR, the additional EABR was done in general anesthesia right before the cochlear implantation. We used the MED-EL auditory nerve test system (= ANTS) for intra-cochlear stimulation [5, 6]. The ANTS stimulation electrode (Figure 1) is an 18 mm cochlear electrode with three stimulating contacts and a ground lead. It is connected to the clinical programming interface MED-EL MAX via the stimulator box for impedance check and stimulation of the auditory pathway (Figure 2). By switching the circuit on the Stimulator Box, several possibilities of stimulation are possible (bipolar and monopolar).

Post-operatively, EABR was recorded at first fitting, stimulating each individual electrode via the clinical software MAESTRO.

Electrode placement was confirmed with the MED-EL Impedance Field Telemetry (IFT). For intra-op. EABR using test electrode and EABR using CI stimulation stimulation, we used an alternating biphasic pulse at a stimulation rate of 34 Hz. The stimulation amplitude started at an amplitude of 100 cu (≈ 100µA) and was increased in 100 cu steps till a possible response. Afterward, smaller steps between this step size were taken individualized. The pulse width was set to 60 µs as a standard setting. For EABR using CI stimulation, the same setting was used but the phase duration was 40µs.

The recording of intra-op. EABR using test electrode and EABR using CI stimulation was performed by a Nihon Kohden Neuropack S1 MEB9400 evoked potential system. The MED-EL MAXs’ trigger output was connected to the trigger input of the EP system. Spes medica® corkscrew electrodes were applied on the contralateral mastoid and ipsilateral tragus (inverting), high forehead (non-inverting), and lower forehead (ground). We used a band-pass filter of 50 Hz to 3000 Hz. Per waveform, 1000 sweeps were collected and averaged. The rejection level was set to +/- 40 µV.
3 Results

Six subjects were included in this study (Table 1). In these subjects, four left and two right ears were tested. The etiology was unknown in three cases, in two cases a tumor or the removal of a tumor, and in one case a syndrome was associated with deafness. Subject numbering was copied from previously performed investigations to allow an easier overview of subjects undergoing pre-op. EABR.

Table 1: Subject demographics.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Side</th>
<th>Etiology</th>
<th>Age at test</th>
</tr>
</thead>
<tbody>
<tr>
<td>S21</td>
<td>Left</td>
<td>Unknown</td>
<td>68</td>
</tr>
<tr>
<td>S22</td>
<td>Left</td>
<td>Tumor removal</td>
<td>59</td>
</tr>
<tr>
<td>S23</td>
<td>Left</td>
<td>Syndrome</td>
<td>55</td>
</tr>
<tr>
<td>S27</td>
<td>Right</td>
<td>Unknown</td>
<td>22</td>
</tr>
<tr>
<td>S28</td>
<td>Left</td>
<td>Unknown</td>
<td>42</td>
</tr>
<tr>
<td>S35</td>
<td>Right</td>
<td>Tumor</td>
<td>52</td>
</tr>
</tbody>
</table>

Only one subject, S21, pre-op. EABR as well as pre-op. EALR, were positive. In all other cases, the results of pre-op. EABR and pre-op. EALR were not matching. The intra-op. EABR using test electrode results were positive in four of six subjects including S21. The intra-op. EABR using test electrode was re-checked intra-operatively via EABR using CI stimulation. The morphology of intra-op. EABR using test electrode is very similar to EABR using CI stimulation, and electrical artifact does not prevent the EABR peaks analysis.

Among these subjects, only two subjects could be tested post-operative with CI due to time constrain during fitting session. The results of the intra-operative EABR using CI stimulation were matching with the intra-op. EABR using test electrode results in all six cases. An overview of results in EABR and EALR is shown in Table 2.

Post-operatively, a EABR, and a EALR were performed in two cases (S21 and S22). In S21, the allover positive results of the previous tests were confirmed by positive post-operative EABR and EALR. In S22, pre- and intra-op. EABR and EALR showed positive results for EABR but insecure results for EALR. This finding of positive auditory brainstem but the insecure auditory cortical response was confirmed by post-operative EABR and EALR respectively.

In Figure 3, the waveforms of subject S28 show an insecure response in pre-op. EABR but a positive response in pre-op. EALR pre-operatively and positive response intra-operatively via intra-op. EABR using test electrode as well as EABR using CI stimulation are displayed. In contrast to pre-op. EABR, the response waves of intra-op. EABR using test electrode did not gather to an eII/III and eIV/V complex but looked similar to intra- or post-operatively recorded EABR in CI stimulation.

Table 2: Subject results in pre-, intra-, and post-operative EABR and EALR measurements. The individual result is given as presence of the response (= ●), missing response = Ø), maybe/possible response (= ?), or not measured (= -).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-operative</th>
<th>Intra-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EABR</td>
<td>EALR</td>
<td>ANTS-EABR</td>
</tr>
<tr>
<td>S21</td>
<td>●</td>
<td>-</td>
<td>●</td>
</tr>
<tr>
<td>S22</td>
<td>●</td>
<td>?</td>
<td>●</td>
</tr>
<tr>
<td>S23</td>
<td>?</td>
<td>?</td>
<td>●</td>
</tr>
<tr>
<td>S27</td>
<td>Ø</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>S28</td>
<td>?</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>S35</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Figure 3: EABR recording in subject 28 pre-operatively using LA-TT-EABR (black); intra-operatively using ANTS-EABR (= intra-op. EABR using test electrode; red) at apical, mid, and basal electrode; post-operatively CI-EABR (blue) at apical, mid, basal and electrode. EABR wave eII, eIII and eV are marked with black lines. Doubt response is marked with ‘?’. Vertical scale is depicted on the top right.
4 Discussion

In doubtful pre-operative results of pre-op. EABR, the use of intra-op. EABR using test electrode can be helpful to re-check insecure results in local anesthesia. Intra-operative EABR using CI stimulation showed the same results as intra-op. EABR using test electrode right before cochlear implantation. This finding confirms the reliability of EABR via the test electrode system ANTS in comparison to the established way of stimulation using a CI. The two cases where post-operative EABR and EALR were already performed showed matching results, too. We expect with very confidence that the two subjects who had EABR using CI stimulation intra-op, will have also EABR using CI stimulation post-op. Further investigation is needed to evaluate the comparison of pre-op. EALR and post-operative EABR using CI stimulation and EALR in a bigger and more complete dataset. The additional time of ANTS electrode placement and EABR using the intra-op. EABR using test electrode is about 10-15 minutes, therefore not a critical factor during a standard CI surgery. The ANTS electrode is a flex type electrode 18.3 mm long, much shorter of typical MED-EL CI electrode (Flex28 is 28 mm, FlexSoft is 31.5 mm). This still gives possibility to stimulate the basal and medium cochlea nerve fibers, minimizing the possible hearing trauma due to electrode insertion, and leaving untouched the rest of the cochlea.

5 Conclusion

In the recent years pre-operative objective tests to assess CI candidacy (for example pre-op. EABR in local anestesia like in this study) are gaining more application and trust among hearing centers for assessment of difficult CI candidates [2]. In case such tests still fail to judge auditory nerve excitability, a last chance before CI implantation is intra-operative assessment done by recording EABR with a test electrode. From our preliminary data, the intra-op. EABR using test electrode is about 10-15 minutes, therefore not a critical factor during a standard CI surgery. The ANTS electrode is a flex type electrode 18.3 mm long, much shorter of typical MED-EL CI electrode (Flex28 is 28 mm, FlexSoft is 31.5 mm). This still gives possibility to stimulate the basal and medium cochlea nerve fibers, minimizing the possible hearing trauma due to electrode insertion, and leaving untouched the rest of the cochlea.

Author Statement

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References