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Intraoperative Monitoring of Hearing During Cerebellopontine Angle Tumor Surgery Using Transtympanic Electrocochleography

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Abstract

Objective—To investigate the use of transtympanic electrocochleography (TT-ECoChG) analyzed on-line by a detector strategy software that made possible automatic extraction of TT-ECoChG components intraoperatively in real-time domain.

Patients—Fifteen patients with cerebellopontine angle tumor among 50 patients were included in this study.

Intervention—All subjects were operated on via middle fossa or retrosigmoid approach. Pure-tone average (PTA) was measured at 0.5, 1.0, and 2.0 kHz, and calculations were performed before and after surgery. Auditory function was monitored intraoperatively via TT-ECoChG, and analyzed data were displayed on-line.

Main Outcome Measures—TT-ECoChG changes in morphology were described. Postoperative PTA elevation level correlated with TT-ECoChG morphology changes occurring intraoperatively.

Results—Analyzed on-line, TT-ECoChG data were displayed as first negative peak of compound action potential amplitude and latency in time domain every 3 to 5 seconds. A good correlation between postoperative PTA elevation and TT-ECoChG morphology changes was showed (Spearman rank test, $R = +0.93$; $t_{(N-2)} = 9.00$; $p < 0.0001$).

Conclusion—TT-ECoChG seemed to effectively mirror even minimal changes in auditory function during intraoperative monitoring in real-time domain. Developed strategy of online analysis makes the intraoperative hearing status assessment faster and easier.

Keywords

Electrocochleography; Cerebellopontine angle tumor surgery; Intraoperative monitoring of hearing; Hearing preservation

Intraoperative monitoring (IM) of cochlear nerve and auditory pathway in patients with cerebellopontine angle (CPA) region pathology has been used during the last 20 years (1-8).

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Such IM may be performed in three electrophysiological options: the monitoring of auditory brainstem responses, direct recording of cochlear nerve action potential, and near-field electrocochleography (ECoChG). In CPA region surgery, ECoChGs may be recorded using three techniques: extratympanic, tympanic, and transtympanic (TT) capture (1,2,4,6-8). Signals acquired from the promontory (i.e., transtympanic) have higher amplitudes requiring fewer samples for averaging to get an interpretable response.

A strategy of monitoring with automatic on-line analysis displaying ECoChG morphology parameters such as a first negative peak of compound action potential amplitude (CAP-N₁-Amplitude) and latency (CAP-N₁-Latency), reflecting changes in hearing status with a minimal delay of no more as 3 to 5 seconds, would seem useful clinically. The aim of this study was to investigate the use of TT-ECoChG for real-time IM of hearing status in humans during CPA tumor (CPAT) surgery with simultaneous on-line display and analysis according to earlier elaborated strategy (5,9).

PATIENTS AND METHODS

This report is on application of a new strategy of IM of auditory function using TT-ECoChG analyzed on-line during CPAT surgery. Fifteen patients with CPATs and hearing thresholds making possible IM, in age ranging from 24 to 66 years, were diagnosed and underwent surgery in the Central Hospital of Medical University of Warsaw between 2004 and 2005. In all of them, imaging and audiological tests including electrophysiology were performed. Pure-tone average (PTA) was calculated for 0.5, 1.0, and 2.0 kHz, and measurements were performed 7 days before and approximately 4 weeks after surgery. PTA elevation was calculated as a difference between postsurgery and presurgery PTA. All electrophysiological recordings were performed using IHSys Smart EP equipment (Intelligent Hearing Systems, Inc., Miami, FL, U.S.A.). In ears that qualified for IM, CAP-N₁-Amplitudes ranged between 0.5 and 7 μ V for click stimulation of 75 to 85 dB normal Hearing Loss (nHL). This 15-patient group with postoperatively confirmed schwannoma was selected among more than 50 patients with CPAT, and these patients were operated on via middle fossa or retrosigmoidal approach. Preoperative hearing status (hearing threshold level measured at 0.5 Hz and 1.0 KHz better than 50 dB HL, speech discrimination test equal or better than 50%, tympanogram type A in impedance audiometry, and CAP-N₁-Amplitude measured in preoperative TT-ECoChG not worse than 0.5 μ V) and tumor size (tumor located in the internal acoustic canal [IAC] or exceeded it no more than 1.5 cm) were the inclusion criteria.

All measurements were recorded via TT-coated needle electrode (-) placed on the promontory. The reference electrode (+) was placed on the vertex, whereas background electrode was placed in the midline forehead close to the hair/skin line.

Each click delivered via insert earphone was presented continuously in the course of surgery in alternating polarity, at a rate of 21.3 per second, and 64 to 128 sweeps were averaged. The system took approximately 3 to 4 seconds to obtain a repeatable and readable response. The protocol was repeated continuously during CPAT surgery.

All recorded data were analyzed on-line using a detector strategy software that made possible automatic extraction of CAP-N₁-Amplitude, CAP-N₁-Latency, cochlear microphonics, and summation potential from recorded TT-ECoChG as previously described by Bohorquez et al. (9). In this study, the authors focused only on automatic analysis of CAP-N₁-Amplitude and CAP-N₁-Latency of TT-ECoChG because these parameters seemed to contribute the most important intraoperative information regarding hearing status. All analyzed recordings were displayed in real time.

All data were subjected to nonparametric Wilcoxon test and Spearman rank test to compare preoperative and postoperative audiometric performance; $p < 0.05$ was considered statistically significant.

RESULTS

Three distinguishable intraoperatively recorded TT-ECochG change patterns were observed: pattern A, with minimal changes in TT-ECochG morphology (CAP-N₁-Amplitude reduced no more than 25% of presurgical value and CAP-N₁-Latency delayed no more than 0.2 ms as compared with the presurgical latency); pattern B, with large changes in TT-ECochG morphology (CAP-N₁-Amplitude reduced more than 25% of presurgical value and CAP-N₁-Latency delayed 0.2 ms or more as compared with the presurgical latency or CAP-N₁/P₁-Amplitude reduced more than 40% of presurgical value irrespective of the latency delay); and pattern C, with loss of TT-ECochG (no response) as a result of intraoperative surgical maneuvers.

Figure 1 shows the sequence of TT-ECochG (pattern A), recorded in the course of a number of surgical maneuvers that put the auditory structures at risk during CPAT removal. In this recording, critical episodes were found to be drilling and compression/stretching of the IAC contents during tumor removal, resulting in TT-ECochG fluctuations. In one moment of the surgery, CAP-N₁-Amplitude was reduced more than 50%, and CAP-N₁-Latency was delayed more than 0.2 ms (points 2 and 5). Fortunately, periods during which TT-ECochG morphology was changed significantly were relatively short, and TT-ECochG morphology recovered to baseline presurgical levels. In this patient, postsurgery PTA elevation was 3.3 dB.

Figure 2 is an example of dramatic morphology changes of TT-ECochG with final disappearance of TT-ECochG (pattern C). IM revealed numerous TT-ECochG fluctuations as an effect of drilling, microbleeding from tumor mass with the use of bipolar cautery, and various manipulations taking place during tumor mass reduction. The surgeon then stopped all manipulations to allow the auditory anatomical structures to “rest.” TT-ECochG began recovery after this pause. During removal of the main mass of tumor, a severe TT-ECochG reduction was observed. After this event, TT-ECochG never returned to presurgical pattern. Only summation potential recovered to, and even surpassed, the baseline value (i.e., overshoot), but the accompanying CAP-N₁-Amplitude recovered only slightly and, ultimately, all details of TT-ECochG recording irreversibly disappeared. In this patient, postsurgery PTA elevation was 66.7 dB.

In patients monitored intraoperatively, in whom pattern B was observed, TT-ECochG morphology recorded in the course of surgery run similarly to the first stage of the previously described subject (look at points 1-14).

Preoperative PTAs in the group of 15 successfully monitored patients ranged from 21 to 63 dB HL (median, 38.3; average, 39.8; standard deviation [SD], 13.8 dB HL), whereas 4 weeks after surgery, PTA ranged from 36 to 92 dB HL (median, 65; average, 70.7; SD, 21.4 dB HL). Nonparametric Wilcoxon test showed significant postsurgery PTA worsening ($p < 0.001$; $z = 3.4$). Postsurgery PTA elevations ranged from 1.5 to 70 dB (median, 21.7; average, 31.0; SD, 27.5 dB). In patients in whom little or no postsurgery TT-ECochG changes were observed (pattern A), postsurgery PTA elevation ranged from 1.7 to 8.3 dB ($n = 5$; median, 3.3; average, 4.0; SD, 2.8 dB). For patients in whom large postsurgery TT-ECochG changes were observed (pattern B), postsurgery PTA elevation ranged from 10 to 21.7 dB ($n = 3$; median, 10; average, 13.9 ± 6.1 dB). For patients in whom postsurgery TT-ECochG was completely lost (pattern C), the observed postsurgery PTA elevation ranged from 38.3 to 70 dB ($n = 7$; median, 60; average, 57.6 ± 12.5 dB). In patients with preserved hearing, PTA elevation ranged from 1.7

to 21.7 dB ($n = 8$; median, 6.7; average, 7.7 ± 1.9 dB). Nonparametric Spearman rank test revealed a very high correlation between intraoperative TT-ECochG status and postsurgery PTA elevation ($R = +0.93$; $t_{(N-2)} = 9.00$; $p < 0.0001$).

DISCUSSION

The TT-ECochG monitoring protocol presented in this article provides the following: 1) information regarding hearing status in real-time domain, 2) performing on-line analysis of the ECochG features CAP-N₁-Amplitude and CAP-N₁-Latency by automatic detection, and 3) displaying of recorded and analyzed data. Performed measurements were made as close to real-time as possible providing surgeons with timely information from which they could make appropriate management decisions. Such updated information may play an important role in hearing preservation during CPAT surgery (1-8).

This study showed that postoperative hearing status in monitored patients corresponded to the final intraoperative changes in ECochG parameters. IM of hearing status via TT-ECochG revealed that the most critical moments of surgery for hearing were found to be 1) drilling of the wall of the IAC and near the cochlea and superior semicircular canal, 2) compression and stretching of the eighth nerve complex during tumor debulking, and 3) application of bipolar cautery (2,4-6). These events were associated with significant reduction of CAP-N₁-Amplitude, accompanying prolongation of CAP-N₁-Latency, and reduction of P1-Amplitude.

In contrast to the present study, Lenarz and Ernst (2) presented several patients in which ECochG disappearance did not correspond with postoperative profound hearing loss. The reason for their findings is unclear, but might be attributed to unrecognized technical recording issues. Theoretically, the opposite situation may arise in which ECochG is preserved, and hearing is lost by selective damage of the cochlear nerve at the brainstem. Some experimental and clinical cases have been described in which intraoperative monitoring via auditory brainstem response and ECochG showed no wave V with simultaneously present CAP-N₁ (7,10). This represents one potential limitation of TT-ECochG as an IM tool.

CONCLUSION

1. As a tool for IM of auditory function, TT-ECochG morphology changes corresponded to certain surgical maneuvers and, when TT-ECochG failed to recover at the end of surgery, correlated well with postsurgical hearing.
2. Stretching the eighth nerve, drilling the IAC posterior or superior wall/close to the cochlea/close to posterior semicircular canal, and application of bipolar cautery near the IAC contents were found to be the most dangerous manipulations affecting TT-ECochG recordings during tumor removal procedures.
3. A good cooperation between audiologist and surgeon during CPAT surgery may modify surgical maneuvers intraoperatively, depending on recorded TT-ECochG changes. Potentially, that interaction prevented irreversible damage to the auditory structures and function in some patients.

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FIG. 1.

Recording showing an example of intraoperative monitoring of hearing status via TT-ECoG. In this patient, postoperative TT-ECoG was preserved with little changes (pattern A). A, Analyzed and displayed CAP-N₁-Amplitude and CAP-N₁-Latency values expressed as normative (%) data. B, ECoG morphology changes. The numbers show particular events that happened during surgery: point 1, reference data; point 2, IAC wall drilling; point 3, recovery; points 4 to 7, compression/stretching of the IAC contents during tumor removal, resulting in ECoG fluctuations; point 8, ECoG recorded just after surgery. In this patient, preoperative PTA was equal to 40 dB HL, postoperative PTA was 43.3 dB HL, and postsurgery PTA elevation was 3.3 dB.

FIG. 2.

A and B. Recording showing an example of intraoperative monitoring via TT-ECoG with failed hearing preservation. A number of fluctuations were observed that finally caused total disappearing of TT-ECoG. The A₁ and A₂ parts of the graph show analyzed and displayed CAP-N₁-Amplitude and CAP-N₁-Latency values expressed as normative (%) data. The B₁ and B₂ parts of the graph present pictures of TT-ECoG morphology changes recorded intraoperatively during tumor removal. The numbers show particular events that happened during surgery: point 1, reference data; point 2, IAC wall drilling; point 3, recovery; points 4 to 5, microbleeding from tumor mass with the use of bipolar cautery; points 7 to 9, various manipulations taking place during tumor mass reduction; points 9 to 11, the surgeon stopped all manipulations to allow the auditory anatomical structures to “rest,” TT-ECoG began

recovery after this 5-minute pause; point 12, recovery; points 13 to 15, at the last stage of the surgical procedure, during removal of the main mass of tumor, a severe TT-ECochG reduction was observed; point 16, the surgeon stopped all manipulation for 5 minutes; points 17 to 19, TT-ECochG began to recover but never returned to baseline presurgical pattern. The summation potential recovered to, and even surpassed, the baseline value (i.e., overshoot), but the accompanying CAP-N₁-Amplitude recovered only slightly; points 20 to 25, remnants of tumor removal, simultaneously recorded TT-ECochG/summation potential is being reduced; point 26, ultimately, all details of TT-ECochG recording disappeared irreversibly at the end of surgery. In this patient, preoperative PTA was equal to 25 dB HL, postoperative PTA was 91.7 dB HL, and postsurgery PTA elevation was 66.7 dB.