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Original Article

Can Electrocochleography Predict Pure Tone Thresholds Without Correction Factors?

Hatice Kübra Bozkurt[1], Ceren Karaçaylı[1,2], Bülent Satar[3]

[1]Department of Audiology, Gülhane Faculty of Health Science, University of Health Science, Ankara, Türkiye
[2]Department of Otorhinolaryngology, Gülhane Training and Research Hospital, University of Health Science, Ankara, Türkiye
[3]Department of Otorhinolaryngology, Gülhane Faculty of Medicine, University of Health Science, Ankara, Türkiye

ORCID IDs of the authors: H.K.B. 0000-0003-3189-058X, C.K. 0000-0002-1995-0589, B.S. 0000-0002-1079-2393.

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BACKGROUND: Electrocochleography (EcochG) is a valuable method for determining frequency-specific objective hearing thresholds. While pure tone audiometry (PTA) is the gold standard, it can be inconclusive in certain populations, such as infants and non-responders. Auditory brainstem response is the primary electrophysiological test for threshold estimation in these groups. However, EcochG offers the advantage of closer field measurements, making it a promising alternative. This study compares PTA-based subjective thresholds with EcochG-derived objective thresholds in patients with varying degrees of hearing loss.

METHODS: Participants consisted of individuals with both normal hearing and varying degrees of hearing loss. 0.5, 1, 2, and 4 kHz tone-burst stimuli and click stimuli were used to measure the latency and amplitude of action potentials (APs) using extra-tympanic electrodes. The AP component of the EcochG response was used as the primary measure for estimating hearing thresholds and was compared with PTA data.

RESULTS: There is a strong correlation between 0.5, 1, 2, and 4 kHz pure tone thresholds (PTTs) and EcochG thresholds of the same frequencies ($P < .001$). Also, there is a strong correlation between click stimulus and the 4-frequency pure tone average ($P < .001$). The results of the linear regression analysis showed that the 0.5, 1, 2, and 4 kHz PTTs can be predicted using EcochG. Electrocochleography with click stimuli can also predict PTA of 4 frequencies.

CONCLUSION: Using the EcochG test, hearing thresholds can be estimated without the need for a correction factor according to our results.

KEYWORDS: Action potential, correction factor, electrocochleography, pure tone audiometry, tympanic membrane electrode

INTRODUCTION

Pure tone audiometry (PTA) is the gold standard for obtaining behavioral thresholds and audiometric configuration in adults. However, this test is subjective and not always feasible, especially in uncooperative patients with some psychomotor impairments.[1] An examination series that records and analyzes physiological responses of the auditory system is referred to as objective electrophysiologic audiometry. Otoacoustic emissions, auditory brainstem responses (ABR), and auditory steady-state responses are a few examples of these electrophysiologic tests. They examine the auditory system's operation at all levels, including the auditory cortex. As a result, objective electrophysiologic audiometry primarily aids in identifying hearing thresholds, finding lesions on the auditory pathways, and screening for hearing loss or retrocochlear injury.[2] Electrocochleography (EcochG) is an objective test that collects electric responses of the inner ear and distal auditory nerve to sound stimuli. The early components are the cochlear microphonic and the summating potential (SP); the later component is the compound action potential (AP).[3] Electrocochleography potentials can be recorded by transtympanic (TT-EcochG) and extra-tympanic (ET-EcochG) recording techniques. Although recording using TT electrodes placed on the promontorium is reliable, it is an invasive technique that may preclude routine use. An alternative to this invasive TT-EcochG is the use of an ET recording electrode placed in the external ear canal or on the lateral surface of the tympanic membrane (TM-electrode). This method is a non-invasive and relatively fast procedure.[4] Although the response amplitudes of ET-EcochG are 4 times smaller than TT-EcochG responses due to its distance from the neural source, ET-EcochG is preferred in clinical audiology due to its less invasive and patient-friendly nature. Of the extratympanic electrodes, the TM-electrode may be

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Corresponding author: Hatice Kübra Bozkurt, e-mail: odyhkbozkurt@gmail.com
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prioritized as a recording technique as it provides larger amplitude responses, smaller SP/AP ratios, lower AP thresholds, and less variability compared to the ear canal TipTrode electrode.[5]

The first intraoperative EcochG measurements in humans were made by Perlman and Case in 1941. However, with the development of recording technology in the eighties, ABR became more popular in clinical audiology to objectively assess hearing thresholds, as they cover a wider range of the auditory pathway from the cochlear nerve.[6] But, over the last 40 years, many researchers have reported the clinical benefits of combining both EcochG and ABR in a simultaneous manner.[7] Electrocochleography and ABR offer the possibility to identify the diagnosis of hearing loss. In the absence of a clear ABR response, it is difficult to determine whether it is the result of cochlear damage or central auditory dysfunction. Especially in cases of auditory neuropathy, prematurity, and dysmaturity, the EcochG has higher reliability offering more precise threshold information. It can also be used to assess hearing thresholds because EcochG has been shown to correlate with pure tone thresholds (PTTs), albeit somewhat erratically.[8,9]

The aim of this study was to find out how accurately EcochG predicts pure-tone hearing thresholds using AP thresholds.

METHODS

This study includes 21 volunteers with a mean age of 48.95 ± 10.42. Ten of the participants were female, while 11 of the participants were male. Four participants had hearing thresholds of no greater than 25 dB HL (hearing level), while 4 had mild, 7 had moderate, and 6 had moderate-severe hearing loss. One of these participants had conductive hearing loss, 3 had mixed hearing loss, and 13 had sensorineural hearing loss. The study was designed prospectively, and the study subjects were selected randomly. The study was carried out in line with the Declaration of Helsinki. The Clinical Research Ethics Committee of the University of Health Sciences Gülhane Training and Research Hospitalapproved the study with the registration number 2023/106 (date: July 05, 2023). A written Informed Consent Form was obtained from all participants.

After otological examination, PTTs of the individuals were measured using an AC-40 Audiometer (Interacoustics, Assens, Denmark) with TDH-39 supraaural headphones. Pure tone average was calculated using 0.5, 1, 2, and 4 kHz PTT. Pure tone audiometry test results and EcochG tests performed on the same day were compared. An auditory evoked potential recording system (Eclipse EP 25, Interacoustics) was used to determine the EcochG thresholds of the individuals included in the study. The AP component of the EcochG response was used to predict hearing thresholds. Before the EcochG test, the test ear of each individual was cleaned with a 3% hydrogen peroxide solution. A non-invasive extratympanic electrode (TM-electrode; Sanibel, Denmark) was used. The TM electrode was fixed in place by placing the sponge tip of the insert earphone into the canal. Two stimuli were used: click stimulus and tone-burst (TB) stimulus. EcochG (TM-electrode) test parameters are shown in Table 1. In both click and TB stimuli, the stimulus intensity was decreased until the threshold level at which the AP was last observed in each individual. Action potential latencies and amplitudes were measured. These measurements were performed by 2 different audiologists, and EcochG results were evaluated when a consensus reached regarding the presence of responses. Pure tone threshold obtained at 0.5, 1, 2, and 4 kHz frequencies on the same day for each participant were compared with EcochG thresholds. In addition, EcochG thresholds obtained with click stimulation were compared with the pure tone average.

Table 1. Test Parameters for Recording EcochG (TM-Electrode) in the Present Study

Parameter	Selection
Electrode placement	Active: On tympanic membrane
	Reference: Contralateral mastoid
	Ground: Fpz (low forehead)
Transducer	Insert earphones (ER-3A)
Stimulus	Alternating click stimulus (0.1 ms) 0.5, 1, 2, and 4 kHz TB stimulus (2-0-2 ms)
Stimulus rate	9.7/s (click); 19.7/s (TB)
Presentation	Monaural
Filter setting	10-3000 Hz
Analysis time	−1.0 to 10 ms
Sweeps	1000

Statistical Analysis

Statistical analysis was performed using SPSS version 22 (IBM SPSS Corp.; Armonk, NY, USA). Shapiro–Wilk was used as a normality test. Linear regression analysis was performed to predict hearing thresholds. The correlation between PTTs and EcochG thresholds was determined by Pearson's correlation test. A paired samples *t*-test was used to compare the difference between EcochG thresholds and PTT's.

RESULTS

There is a strong correlation between 0.5, 1, 2, and 4 kHz PTT and EcochG thresholds of the same frequencies, determined by observing

Table 2. Correlation of Electrocochleography Thresholds and Pure Tone Thresholds

	r	*P*
EcochG 500->PTT 500	0.951*	<.001
EcochG 1000->PTT 1000	0.953*	<.001
EcochG 2000->PTT 2000	0.962*	<.001
EcochG 4000->PTT 4000	0.904*	<.001
EcochG Click->PT average	0.898*	<.001

*EcochG, electrocochleography; PTT, pure tone threshold; *r*, Pearson's correlation coefficient.

MAIN POINTS

- There is a strong correlation between 0.5, 1, 2, and 4 kHz pure tone thresholds and electrocochleography (EcochG) thresholds of the same frequencies.
- Our EcochG measurements with tympanic membrane (TM) electrode showed that no correction factor was needed.
- The use of TM electrodes has also been shown to be easy and feasible.

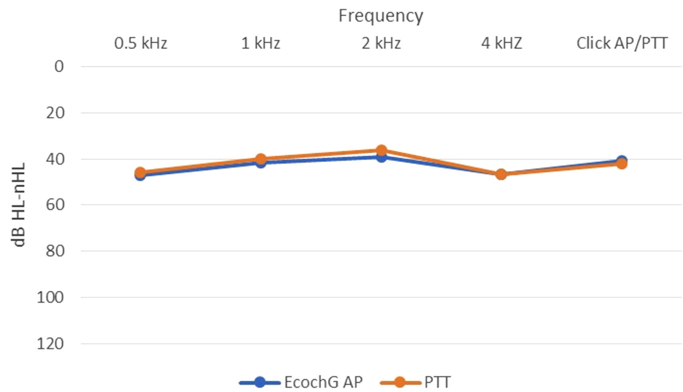

Figure 1. Mean AP threshold obtained by EcochG test with 0.5, 1, 2, and 4 kHz TB stimulus and click stimulus and the mean PTT obtained by pure tone audiometry test in all patients.

the AP component of EcochG during threshold analysis. Also, there is a strong correlation between click stimulus and the 4-frequency pure tone average (Table 2). The average of the 0.5, 1, 2, and 4 kHz PTTs and the average of EcochG thresholds at the same frequencies are shown in Figure 1.

The results of the linear regression analysis showed that the 0.5, 1, 2, and 4 kHz PTTs can be predicted using EcochG. Electrocochleography with click stimuli can also predict the PT average of 4 frequencies (Table 3). As shown in Table 2, the proportion of the variances explained by EcochG thresholds (R^2) is very high. A paired samples *t*-test of the PTT and EcochG thresholds showed no statistical difference across all frequencies, except for 2 kHz. Pure tone thresholds of 2 kHz was found to be significantly lower than the EcochG threshold ($t=2.09$, $P=.045$). The mean PTT of the patients at 2 kHz was 36.364 dB HL, while the mean AP threshold was 39.091 dB nHL (normalized hearing level). Also, there was no statistical difference between PTA and EcochG thresholds with click stimulus.

DISCUSSION

Hearing is required for humans to participate in social interactions and is an important aspect in determining life quality. Unfortunately, hearing loss affects more than 1.5 billion individuals globally, and that number is expected to more than 1.5 times increase in the next 30 years. Thus, otology and audiology specialists are concerned with how to provide medical assistance for hearing loss patients.[10] Hearing sensation is subjective in nature. The gold standard for clinical evaluation is behavioral testing, which includes pure-tone and speech audiometry.[11] Objective metrics that can be used to predict the pure-tone audiogram in patients who cannot produce reliable behavioral reactions to sound have long been needed.[12]

The cochlea and cochlear nerve responses can be recorded using EcochG. It emerged in the late 1960s and helped to lay the groundwork for modern auditory electrophysiological procedures. It was once widely used, but it has since been surpassed by ABR.[2] Electrocochleography, unlike ABR, was found to induce frequency-specific responses at low to moderate stimulus intensities utilizing TB stimulation. The introduction of extratympanic electrodes has brought the EcochG test back to the agenda.[13] There are some special circumstances that make the EcochG test stand out, and it is still a useful test today. For example, in cases with severe to profound sensorineural hearing loss (SNHL) and inadequate response to amplification with hearing aids, frequency-specific EcochG is used to confirm the diagnosis of auditory synaptopathy/neuropathy and the indication for cochlear implantation.[14] In their recent study in children with auditory synaptopathy/neuropathy and profound SNHL, McMahon et al[15] were able to differentiate between auditory synaptopathy and neuropathy (postsynaptic) with specific EcochG waveform patterns and thus identify pre- and postsynaptic sites of lesions.

The most important reason for the replacement of EcochG by ABR is that the ABR recording procedure is much easier than EcochG. However, ABR has certain limitations. Clicks typically reflect hearing sensitivity and synchronization in the frequency band between 2and 4 kHz. ABRs invoked by clicks are unable to evaluate low-frequency (0.5-2 kHz) hearing, which is necessary for speech perception. Tone-burst stimulation allows more closely targeted, narrow-band stimulation and can be utilized at a variety of frequencies.[16] The usual TB-ABR test only detects hearing loss of a certain frequency at a time, but the standard click ABR test lacks adequate neuronal synchrony and mostly examines high-frequency hearing.[17] Some audiologists think that because there is not enough neuronal synchrony or frequency specificity, it is not possible to acquire accurate frequency-specific ABR. Many audiologists continue to employ just click stimuli due to concerns about getting sufficient recordings from naturally sleeping or peacefully awake infants as well as the time needed to collect TB recordings.[18] For this reason, the EcochG test can be particularly advantageous for low-frequency TB measurements. In contrast, EcochG is much more near-field potential than ABR. Recording closer to the distal end of the auditory nerve allows higher wave amplitudes to be recorded.[7] Thus, this study aimed to estimate hearing thresholds using AP obtained from EcochG.

Although EcochG studies now focus on intraoperative monitoring rather than threshold estimation, there is a small amount of literature on this subject. Schoonhoven et al[13] investigated the relationship

Table 3. Linear Regression Analyses Showed that Pure Tone Thresholds and Pure Tone Averages Can be Predicted Using Electrocochleography Thresholds

	BETA0	BETA1	SE	95% CI	R^2	*F*	*P**
EcochG 500->PTT500	0.897	0.951	0.065	0.76-1.034	0.904	187.733	<.001
EcochG 1000->PTT1000	0.953	0.953	0.068	0.812-1.094	0.908	198.265	<.001
EcochG 2000->PTT2000	0.914	0.962	0.058	0.792-1.035	0.925	247.091	<.001
EcochG 4000->PTT4000	0.855	0.904	0.090	0.667-1.043	0.818	89.884	<.001
EcochG Click->PT average	0.913	0.898	0.103	0.697-1.128	0.806	78.705	<.001

*Linear regression enter method.
Beta0, unstandardized coefficient; Beta1, standardized coefficient; EcochG, electrocochleography; *F*, test statistics; PT, pure tone; PTT, pure tone threshold; R^2, determination coefficient; SE, standard error.

between pure tone audiometric thresholds and EcochG thresholds with TT and extratympanic electrodes. They reported that measurements with TT electrodes had a high correlation with audiometric thresholds, but measurements with extratympanic electrodes showed a difference of approximately 16 dB between PTTs and EcochG thresholds. Although we also used extratympanic electrodes (TM electrode), we found a very high correlation between PTTs and EcochG thresholds. In fact, when EcochG averages were compared with PTT averages, it was observed that there was a difference between the averages only for 2 kHz frequency and this difference was approximately 3 dB.

One disadvantage of ABR is that it fails to estimate low frequency thresholds more accurately than high frequency thresholds.[19] The use of EcochG may be recommended instead of ABR, especially in patients with low frequency hearing loss. Our study has shown that there is a very high correlation between PTTs and EcochG thresholds at all frequencies. There is no statistically significant difference between the PTTs and EcochG thresholds except at 2000 Hz. The difference between 2000 Hz EcochG hearing thresholds and PTT averages was only 3 dB. Since the TM-electrode was used in our study, it is not an invasive test method, and the patients did not mention any complaints during the test. This may enable EcochG to replace ABR in the estimation of hearing thresholds without a correction factor, especially in patients with low frequency loss.

Our primary limitation in this study was the small number of patients. In future studies, both ABR and EcochG thresholds can be compared in the same patient to provide a clearer understanding of PTT estimation. Additionally, simultaneous extratympanic recordings of ABR and EcochG have been shown to enhance threshold estimates by providing complementary data, as they allow for more accurate and comprehensive assessments of auditory function, as demonstrated in previous studies.[7] Future research could benefit from this combined methodology to refine the accuracy of hearing threshold estimation.

CONCLUSION

In conclusion, according to the findings of this investigation, AP obtained from the EcochG test is highly correlated with hearing thresholds (the audiogram). Using the EcochG test, hearing thresholds can be estimated without the need for a correction factor according to our results.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author upon reasonable request .

Ethics Committee Approval: This study was approved by the Ethics Committee of the University of Health Sciences Gülhane Training and Research Hospital (approval no.: 2023/106; date: July 05, 2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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REFERENCES

1. Chen CH, Lin HH, Wang MC, et al. Diagnostic accuracy of smartphone-based audiometry for hearing loss detection: meta-analysis. *JMIR MHealth UHealth*. 2021;9(9):e28378. [CrossRef]
2. Bakhos D, Marx M, Villeneuve A, Lescanne E, Kim S, Robier A. Electrophysiological exploration of hearing. *Eur Ann Otorhinolaryngol Head Neck Dis*. 2017;134(5):325-331. [CrossRef]
3. Hatzopoulos S, Ciorba A, Krumm M. *Advances in audiology and hearing science*. Cambridge: Apple Academic Press; 2020.
4. Zakaria MN, Nik Othman NA, Musa Z. Does the location of electrode on tympanic membrane matter when recording electrocochleography? *Acta Otolaryngol*. 2021;141(11):984-988. [CrossRef]
5. Lefler SM, Kaf WA, Ferraro JA. Comparing simultaneous electrocochleography and auditory brainstem response measurements using three different extratympanic electrodes. *J Am Acad Audiol*. 2021;32(6):339-346. [CrossRef]
6. Coraci LM, Beynon AJ. Use of an extra-tympanic membrane electrode to record cochlear microphonics with click, tone burst and chirp stimuli. *Audiol Res*. 2021;11(1):89-99. [CrossRef]
7. Minaya C, Atcherson SR. Simultaneous extratympanic electrocochleography and auditory brainstem responses revisited. *Audiol Res*. 2015;5(1):105. [CrossRef]
8. Cumpston E, Totten DJ, Hohman MH. Electrocochleography. In: *StatPearls*. Treasure Island, FL: StatPearls Publishing Copyright © 2024, StatPearls Publishing LLC.; 2024.
9. Aimoni C, Ciorba A, Bovo R, Trevisi P, Busi M, Martini A. Hearing threshold assessment in young children with electrocochleography (EcochG) and auditory brainstem responses (ABR): experience at the University Hospital of Ferrara. *Auris Nasus Larynx*. 2010;37(5):553-557. [CrossRef]
10. Li Z, Lai X, Lai J, et al. Correction of the estimated hearing level of NB chirp ABR in normal hearing population. *Audiol Neurootol*. 2022;27(5):388-396. [CrossRef]
11. Noh H, Lee DH. Discrepancies in hearing thresholds between pure-tone audiometry and auditory steady-state response in non-malingerers. *Ear Hear*. 2020;41(3):663-668. [CrossRef]
12. Gorga MP, Johnson TA, Kaminski JR, Beauchaine KL, Garner CA, Neely ST. Using a combination of click- and tone burst-evoked auditory brain stem response measurements to estimate pure-tone thresholds. *Ear Hear*. 2006;27(1):60-74. [CrossRef]
13. Schoonhoven R, Prijs VF, Grote JJ. Response thresholds in electrocochleography and their relation to the pure tone audiogram. *Ear Hear*. 1996;17(3):266-275. [CrossRef]
14. Stuermer KJ, Beutner D, Foerst A, Hahn M, Lang-Roth R, Walger M. Electrocochleography in children with auditory synaptopathy/neuropathy: diagnostic findings and characteristic parameters. *Int J Pediatr Otorhinolaryngol*. 2015;79(2):139-145. [CrossRef]
15. McMahon CM, Patuzzi RB, Gibson WP, Sanli H. Frequency-specific electrocochleography indicates that presynaptic and postsynaptic mechanisms of auditory neuropathy exist. *Ear Hear*. 2008;29(3):314-325. [CrossRef]
16. Kerneis S, Caillaud E, Bakhos D. Auditory brainstem response: key parameters for good-quality recording. *Eur Ann Otorhinolaryngol Head Neck Dis*. 2023;140(4):181-185. [CrossRef]

17. Jiang Y, Samuel OW, Zhang H, Chen S, Li G. Towards effective assessment of normal hearing function from ABR using a time-variant sweep-tone stimulus approach. *Physiol Meas*. 2021;42(4):10.1088/1361-6579/abcdf2. [CrossRef]
18. Elsayed AM, Hunter LL, Keefe DH, et al. Air and bone conduction click and tone-burst auditory brainstem thresholds using Kalman adaptive processing in nonsedated normal-hearing infants. *Ear Hear*. 2015;36(4):471-481. [CrossRef]
19. Almohammad HA, Chertoff ME, Ferraro JA, Diaz FJ. Auditory nerve phase-locked response recorded from normal hearing adults using electrocochleography. *Int J Audiol*. 2023;62(2):172-181. [CrossRef]