# COMPARISON OF CLICK AND TONE BURST INDUCED ELECTROCOCHLEOGRAPHY IN INDIVIDUALS WITH NORMAL HEARING

[1]Prawin Kumar, & [2]Pallavi

**Abstract**

*Electrocochleography (ECochG) is a tool to record the receptor potentials of the cochlea and the whole nerve action potential in individuals with normal hearing and in different clinical population. The present study aimed to see the difference in performance between click and 1000 Hz tone burst stimuli in individuals with normal hearing. There were ten ears with normal hearing individuals in the age range of 18 to 25 years. The results of the study revealed a significant difference for latency measurements of summating potential and action potential between click and 1000 Hz tone burst stimuli at $p < 0.01$ level. However, there were no statistically significant difference for amplitude measurements of summating potential and action potential between click and 1000 Hz tone burst stimuli at $p > 0.05$ level. Furthermore, SP/AP amplitude ratio revealed no statistically significant difference between click and 1000 Hz tone burst stimuli in individuals with normal hearing at $p > 0.05$ level. These finding can be utilized for clinical population in differential diagnosis. However, further studies needs to be carried out on large population in clinical group.*

**Key words:** *summating potentials, action potentials, extratympanic, transtympanic*

Electrocochleography (ECochG) is a measurement of stimulus related electrical potentials, which includes the cochlear microphonics (CM), summating potentials (SP) and compound action potentials (AP) of the auditory nerve. ECochG is an ideal test for the diagnosis of Meniere's disease. It is thought to reflect changes in the anatomic position of the hair cells. This bias in the position of the hair cell is what is expected to occur in active Meniere's disease (Levin, Margolis & Daly, 1998). Thus, ECochG have focused on amplitude measure of SP alone or on the amplitude ratio of SP and AP. The purpose of measuring ECochG include monitoring of cochlear and auditory nerve function during surgery, which could result in compromising of these function, and improving the ease with which wave I is identified during ABR testing. Another area of clinical interest and application of the ECochG response is in differential diagnosis of Meniere's disease.

Several investigators have routinely used transtympanic (TT) recording methods (Eggermont, Odenthal, Schmidt, & Spoor, 1974; Gibson, Prasher, & Kilkenny, 1983; Yoshie, 1976). Others have preferred extratympanic (ET) methods by recording from ear canal wall as it is non-invasive techniques (Coats, 1974; Coats & Martin, 1977; Elberling, 1974) or, recently from the tympanic membrane (TM) (Lilly & Black, 1989; Ruth & Lambert, 1989). Current extratympanic studies focus almost exclusively on the amplitude of the summating potential (SP), either absolute or relative to that of the action potential (AP), as elicited by high-level click stimuli (Coats, 1981; Mori, Asai, Doi, & Matsunaga, 1987). In addition, tone burst stimulation as an extension to clicks is far more often applied in TT than in ET studies (Eggermont, 1976). However, TT technique is invasive technique in nature and tedious to perform. Tone burst stimuli have been used to extend the analysis of SP and SP/AP amplitude ratios (Dauman & Aran, 1991).

ECochG can be elicited with tone burst signals (Campbell, Faloon, & Rybak, 1993; Ge, & Shea, 2002). ECochG measurements with tone burst signals are often applied in the diagnosis of Meniere's disease (Campbell, Harker, & abbas, 1992; Orchik, shea, & Ge, 1993). There is some evidence that the diagnostic value of ECochG is relatively higher for 1000 Hz tone burst frequency (Sass, 1998; Conlon, & Gibson, 2000).

Schoonhoven, Fabius, and Grote (1995) aimed to explore the applicability of ET and TT methods of electrocochleography. They used both clicks and tone burst stimuli to record electrocochleography at different intensity levels. The tone burst stimuli were octave frequencies from 500 Hz to 8000 Hz. The tone burst had a trapezoidal envelope with a 4 msec plateau duration, and with rise/fall time times of two periods of the carrier frequency. They were tried to find out threshold levels by reducing the intensity levels in 10 dB steps started from 90 dB HL. The results revealed that ET responses were reduced in amplitude in comparison to TT responses by a factor of 0.43. However, the latencies were similar for ET and TT recording. It was also found that ET responses to tone burst in normal individuals showed the same response characteristics as found in TT Electrocochleography.

[1]Lecturer in Audiology, All India Institute of Speech and Hearing (AIISH), Mysore-06, prawin_audio@rediffmail.com, [2]Student, AIISH, Mysore-06.

Ghosh, Gupta and Mann (2002) evaluated and compared the results of ET and TT ECochG in individuals with normal hearing and different clinical population. There were 20 individuals with Meniere's disease served as clinical group and 20 age-and gender-matched control (10 of which were those with chronic suppurative otitis media) group in the age ranged from 20 to 61 years. They used clicks as stimuli presented at two different intensity levels (80 dB SPL and 100 dB SPL) for both TT and ET recording. The various parameters compared were summating potential, action potential in terms of latency and amplitude, and ratio of SP/AP amplitude. The results revealed that there were significant difference between control and clinical groups by both methods. They observed the sensitivity of 100% and specificity of 90% for TT method, whereas the ET method showed corresponding values of 90% and 80% respectively. They conclude ET method is less invasive compared to TT method and can be easily performed on clinical population.

## Need for the study

There is an ambiguity in terms of selecting type of stimuli and recording methods to be adopted for ECochG. Study done by Ghosh, Gupta and Mann (2002) used only click as stimuli at two different intensity levels and recorded with both TT and ET methods. However, Schoonhoven, Fabius, and Grote (1995) used clicks as well as different octave frequencies tone burst stimuli from 500 Hz to 8000 Hz to obtain input-output graph for TT and ET recording. In addition to that, later study did recording at different intensity levels starting from 90 dB HL reducing in 10 dB steps till threshold level. Further, they have not specified the stimuli which yielded the best response. Hence, present study was taken up to check the more useful stimuli for recording ECochG in individuals with normal hearing.

## Aim of the study

The aim of the present study to check the difference between click and 1000 Hz tone burst stimuli while recording ECochG. This includes recording of latency and amplitude of summating potential (SP), action potential (AP), and SP/AP amplitude ratios in individuals with normal hearing.

# Method

The present study was conducted with the aim of studying the difference between click and 1000 Hz tone burst stimuli while recording ECochG in individuals with normal hearing.

*Participants*

Total number of ten ears from six normal hearing individuals (1 female & 5 male) was selected. The age range of the participants varied from 17 to 25 years. Participants with any history of otologic or neurologic history were excluded from the study. All the participants were randomly selected from 380 undergraduate / postgraduate programs being conducted in the city of Mysore. Oral consent was obtained from all the participants.

*Participant selection Criteria:*

Individuals having hearing sensitivity less than 15 dB HL at octave frequencies between 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction were selected. They had normal middle ear functioning as indicated by Immittance evaluation. Participants having speech identification scores greater than 90% and having no history of any otologic, neurologic problems were included for this study.

*Instrumentation:*

To carry out the pure tone audiometry and speech audiometry, a calibrated two channels Orbiter-922 diagnostic audiometer with TDH-39 headphone with MX-14/AR ear cushion, and Radio ear B-71 bone vibrator were used. A calibrated immittance meter, GSI-Tympstar was used to assess middle ear functioning. Bio-logic system (version, 7.0) with impedance matched ER-3A insert earphone was used to record and analyse the ECochG.

*Test Environment:*

All the measurement was carried out in an acoustically treated double room situation. The ambient noise level was within the permissible level according to ANSI (1991).

*Test Procedure:*

Pure tone thresholds were obtained with head phones for octave frequencies between 250Hz to 8000Hz for air conduction using modified Hughson-Westlake procedure (Carhart & Jerger, 1959). The tympanometry and acoustic reflex were carried to rule out any middle ear pathology.

*Extratympanic ECochG recording:* Participants were made to sit comfortably in order to ensure a relaxed posture and minimum rejection rate. ECochG was recorded from one channel. Silver chloride (AgCl) electrodes were placed after cleaning the electrode sites with skin preparing gel. TIPTRODE electrode was used for recording ECochG. Conduction paste was used to improve the conductivity of the signal. For ECochG, the non-inverting electrode was placed in the ear canal, ground electrode was placed on the nasion and the inverting electrode was placed on the opposite ear mastoid. The electrodes were secured in place using plasters. The electrode impedance value was kept less than 5 kΩ and the inter electrode difference was less than 3 kΩ.

The click stimuli duration was 100 μsec. with no rise and fall time. The tone burst stimuli of 1000 Hz had 2 msec rise time and 2 msec fall time with 0 msec plateau. Blackman ramp was used for tone burst stimuli. The test protocol is mentioned in the table 1.

Table 1: *Test protocol for Electrocochleography*

| Parameters | Click stimuli | 1000 Hz tone burst stimuli |
|---|---|---|
| Analysis window | 10 msec | 10 msec |
| Gain | 50,000 | 50,000 |
| Filter setting | 10 Hz -1500 Hz | 10 Hz- 1500 Hz |
| Type of stimulus | Click | 1000 Hz |
| Polarity of stimulus | alternating | alternating |
| Repetition rate | 7.1/s | 7.1/s |
| No. Of stimuli | 1000 | 1000 |
| Intensity of the Stimulus | 90 dB nHL | 90 dB nHL |

Latency of summating potential, and action potential was measured. Peak to peak amplitude values of summating potential and action potential was measured. The SP/AP amplitude ratio was also calculated for individuals with normal hearing. Two audiologists independently analyzed the waveform.

## Results

The latency and amplitude of the summating potentials, action potentials and amplitude ratio (SP/AP) were recorded for click and 1000 Hz tone burst stimuli (Figure 1). Mean and standard deviation (SD) was calculated separately for latency and amplitude for click and 1000 Hz tone burst stimuli. Wilcoxon signed ranks test was administered to check if there is a statistically significant difference between the measures obtained with click and 1000 Hz tone burst stimuli. SPSS software (version 17) was used to carry out the statistical analysis.

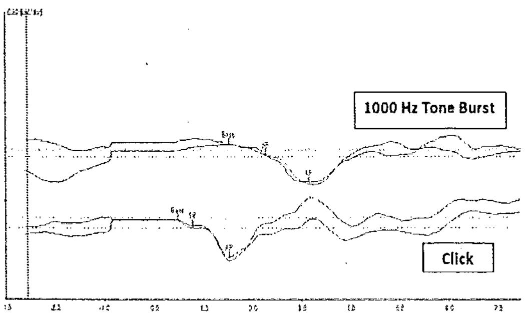


Figure 1: *Sample waveform of click and 1000 Hz Tone Burst stimuli recording*

*Latency measurements for click and 1000 Hz tone burst stimuli*

The mean latency for click stimuli was less than 1000 Hz tone burst stimuli for summating potentials and action potentials. Furthermore, standard deviation was also less for click stimuli than 1000 Hz tone burst stimuli. It indicates that the variability is more for tone burst stimuli than click stimuli (Table 2 & Figure 2).

Table 2: *Mean and SD of Latency for click and 1 kHz tone burst stimuli (N = 10)*

| Types of stimuli | Different parameters of ECochG | Mean (msec) | Standa deviation (SD) |
|---|---|---|---|
| Click | SP | 0.75 | 0.12 |
| | AP | 1.50 | 0.07 |
| 1000 Hz | SP | 2.16 | 0.38 |
| | AP | 3.02 | 0.35 |

The latency range varied for summating potential from 0.57 msec to 0.99 msec for click and from 1.78 msec to 3.11 msec for 1000 Hz tone burst in individuals with normal hearing. In addition, Wilcoxon signed rank test revealed that there is statistically significant difference between click and 1000 Hz tone burst stimuli for summating potential ($Z = 2.80$, $p < 0.01$) and action potential ($Z = 2.80$, $p < 0.01$).

The present finding is in consonance with the finding by different researchers (Schoonhoven, Fabius, & Grote, 1996; Ghosh, Gupta, & Mann, 2002). As per Ghosh et al. (2002), the mean latency for summating potential in individuals with normal hearing using clicks with extratympanic techniques was 0.53 msec at 100 dB SPL and 1.06 msec at 80 dB SPL. Similarly mean latency for action potential was 0.90 msec at 100 dB SPL and 1.55 msec at 80 dB SPL.

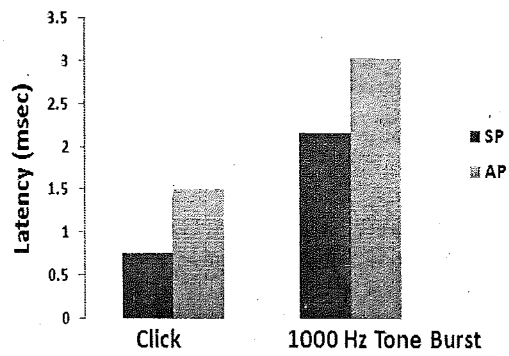


Figure 2: *Latency measurements for summating and action potential*

*Amplitude measurements for click and 1000 Hz tone burst stimuli*

For amplitude measure, the trend was not similar as it was for latency measurements. The mean amplitude for summating potentials and action potential was more for click stimuli than 1000

Hz tone burst stimuli. In addition, SD for click stimuli was more than 1000 Hz tone burst stimuli for summating potential which indicates variability was more for click stimuli than 1000 Hz tone burst stimuli. However, in case of action potential SD was lesser for click than 1000 Hz tone burst stimuli (Table 3 & Figure 3).

Table 3: *Mean and SD of amplitude for click and 1 kHz tone burst stimuli (N = 10)*

| Types of stimuli | Different parameters of ECochG | Mean (msec) | Standard deviation (SD) |
|---|---|---|---|
| Click | SP | 0.10 | 0.28 |
| | AP | 0.57 | 0.27 |
| 1000 Hz | SP | 0.05 | 0.14 |
| | AP | 0.30 | 0.41 |

The range of amplitude for summating potentials varied between 0.01 $\mu$V to 0.57 $\mu$V for click and 0.01 $\mu$V to 0.23 $\mu$V for 1000 Hz tone burst in individuals with normal hearing. Furthermore, Wilcoxon signed ranks test revealed that there is no statistically significant difference between click and 1000 Hz tone burst stimuli for summating potentials ($Z = 0.53$, $p > 0.05$) and action potentials ($Z = 1.47$, $p > 0.05$). In a similar line, Ghosh et al. (2002) reported that the mean amplitude for summating potential in individuals with normal hearing using clicks as stimuli was 1.19 $\mu$V at 100 dB SPL and 0.59 $\mu$V at 80 dB SPL. Similarly, the mean amplitude of action potential was 7.88 $\mu$V at 100 dB SPL and 3.22 $\mu$V at 80 dB SPL.

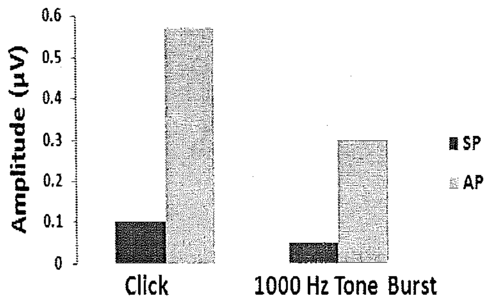


Figure 3: *Amplitude measurements for summating and action potential*

*Amplitude ratio (SP/AP) for click and 1000 Hz tone burst stimuli*

The mean amplitude ratio (SP/AP) was in the range of 0.10 to 0.50 for click and 0.12 to 0.46 for 1000 Hz tone burst stimuli. The mean was almost same for both click and 1000 Hz tone burst stimuli for individuals with normal hearing. The SD was little higher for click than tone burst which indicates variability was more for clicks than tone burst (Table 4). The Wilcoxon signed rank test was performed to check if there is any difference in amplitude ratio (SP/AP) between click and 1000 Hz tone burst stimuli. The results indicated no statistically significant difference between click and 1000 Hz tone burst stimuli ($Z = 0.15$, $p > 0.05$).

Table 4: *Amplitude ratio (SP/AP) for click and 1000 Hz tone burst stimuli*

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Click | 0.26 | 0.13 | 0.10 | 0.50 |
| 1000 Hz | 0.26 | 0.11 | 0.12 | 0.46 |

The present finding is in agreement with the results from different researchers (Ghosh, Gupta, & Mann, 2002). In individuals with normal hearing the amplitude ratio (SP/AP) with extratympanic recording techniques using clicks as stimuli was 0.16 at 100 dB SPL and 0.18 at 80 dB SPL (Ghosh, Gupta, & Mann, 2002).

## Discussion

The objective of our study was to explore the type of stimuli to be used while recording ECochG in extratympanic mode. It is non-invasive mode of recording and less time consuming. It also helps us to understand the physiology behind changes occurring with the use of different stimuli.

In present study, click and 1000 Hz tone burst stimuli were used for recording ET ECochG. As per present finding, click showed better responses in terms of amplitude measure for both summating potential and action potential. However, in terms of latency, 1000 Hz tone burst show better responses than click stimuli. The reported literature suggests that latency is more stable parameter than amplitude measure. Hence, authors suggest use of click stimuli for ECochG recording until frequency specific information is required.

According to Schoonhoven et al. (1995), for any given tone burst intensity, action potential latency increases with decreasing stimulus frequency. The action potential latency for the click is in the same range as the latencies for the 4000 Hz to 8000 Hz tone bursts. In the present study, the latency for 1000 Hz (low frequency) tone burst stimuli was more (prolong) than click (high frequency) stimuli, could be reflection of the tonotopic organization of the cochlea.

In present study, data showed higher amplitude for clicks stimuli than 1000 Hz tone burst stimuli. It could be due to the basal shift of the cochlear activation pattern (Rose, Hind, Anderson & Brugge, 1972). Schoonhoven et al. (1996) also showed that the action potential amplitude increases gradually and latency decreases with increase in stimulus intensity.

In clinical population, amplitude ratio (SP/AP) was assessed using click and tone burst stimuli by Arenberg, Kobayashi, Obert, and Gibson (1993). They reported that when click was used, the amplitude ratio (SP/AP) change was more significant than the change observed measuring the absolute SP amplitude portion of the ratio alone. It was also concluded that the tone burst stimulation gives more frequency specific information, making tone burst more useful in detecting early or different focal types of endolymphatic hydrops. Hence, these authors suggested the use of tone bursts at different frequencies along with clicks could be useful in assessing endolymphatic hydrops.

## Conclusions

It can be concluded from the present study that the different parameters of the ECochG can be assessed using either click or tone burst stimuli through extratympanic recording technique. The parameters which can be assessed are summating potential, action potential and amplitude ratio (SP/AP). These parameters are very helpful in the diagnosis of different pathology of inner ear. The recorded data can be used for reference when administering same test on clinical population. The results of the present study revealed that the latency of summating and action potential for clicks were less than 1000 Hz tone burst. However, the amplitude of the summating and action potential were higher for clicks than 1000 Hz tone burst stimuli with extratympanic recording. The above finding could be because of the tonotopic organization of the cochlea. The amplitude ratio (SP/AP) revealed no significant difference between click and 1000 Hz tone burst stimuli in individuals with normal hearing. However, amplitude ratio (SP/AP) is very important diagnostic tool for clinical population. Hence, further research can be done on clinical population to validate the importance of present finding.

## References


American National Standard Institute (1991). Maximum permissible ambient noise for audiometric test rooms. ANSI S3.1-1991. New York.

Arenberg, I. K., Kobayashi, H., Obert, A. D., & Gibson, W. P. R. (1993). Intraoperative electrocochelеography of endolymphatic hydrops surgery using clicks and tone bursts. *Acta Otolaryngologica (suppl.), 504,* 58-67.

Campbell, K. C., Harker, L. A., & Abbas, P. J. (1992). Interpretation of electrocochelеography in Meneire's disease and normal subjects. *Annals of Oto-Rhino-Laryngology. 101,* 496-500.

Campbell, K. C., Faloon, K. M., & Rybak, L. P. (1993). Non-invasive electrodes for electrocochleography in the chinchilla. *Archive of otolaryngology- Head, Neck and Surgery, 119,* 767-771.

Carhart, R., & Jerger, J. (1959). Preferred methods for clinical determination of pure tone thresholds. *Journal of Speech and Hearing Disorders, 16,* 340-345.

Coats, A. C. (1974). On electrochocleographic electrode design. *Journal of the acoustical society of America, 56,* 708-711.

Coats, A. C. (1981). The summating potential in Meneiere's disease. I. Summating potential amplitude in Meneire's and non-Meneire's ears. *Archives of Oto-Rhino-Laryngology 107,* 199-208.

Coats, A. C., & Martin, J. L. (1977). Human auditory nerve action potentials and brain stem responses. *Archives of Oto-Rhino-Laryngology, 103,* 605-622.

Conlon, B. J. & Gibson, W. P. R. (2000). Electrocochleography in diagnosis of Meniere's disease. *Acta Otolaryngology, 120,* 480-483.

Dauman, R., & Aran, J. M. (1991). Electrochocleography and the diagnosis of endolymphatic hudrops: clicks and tone bursts. In I. K. Arenberg (Ed.), surgery of the inner ear (pp. 123-133). Amsterdam: kugler Publications.

Eggarmont, J. J. (1976). Analysis of compound action potential responses to tone bursts in human and guinea pig cochleas. *Journal of Acoustical Society of America, 60,* 1132-1139.

Eggermont, J. J., Odenthal, D. W., Schmidt, P. H., & Spoor, A. (1974). Electrocochleography: basic principles and clinical application. *Acta Oto-Laryngologica, supplement (Stockhom), 310,* 1-84.

Elberling, C. (1974). Action potentials along the cochlear partition recorded from the ear canal in man. *Scandinavian audiology, 3,* 13-19.

Ge, X., & Shea, J. J. (2002). Tranastympanic electrocochleography: a 10-year experience. *Otology & Neurotology, 23,* 799-805.

Ghosh, S., Gupta, A. K., & Mann, S. S. (2002). Can electrocochleography in Meneire's disease be noninvasive?, *The Journal of Otolaryngology, 31,* 371-375.

Gibson, W. P. R., Prasher, D. K., & Kilkenny, G. P. G. (1983). Diagnostic significance of transtympanic electrocochеleography in Meneire's disease. *Annals of Otology, Rhinology, and Laryngology, 92,* 155-159.

Levin, S., Margolis, R. H. & Daly, K. A. (1998). Use of Electrochleography in the diagnosis of Meniere's Disease. *Laryngoscope, 108,* 993-1000.

Lilly, D. J., & Black, F. O. (1989). Electro cochelography in the diagnosis of Meneire's disease. In J. B. Nadol (Ed.), meneire's disease (pp. 369-374). Amsterdam: Kugler & Ghedini.

Mori, N., Asai, H., Doi, K., & Matsunaga, T. (1987). Diagnostic value of extratympanic electrocochleography in meneire's disease. *Audiology, 26,* 103-110.

Orchik, D. J., Shea, J. J., & Ge, X. (1993). Tranastympanic electrocochleography in Meneire's disease using clicks and tone bursts. *American Journal of Otology. 14*, 290-294.

Rose, J. E., Hind, J. E., Anderson, D. J., & Brugge, J. F. (1972). Some effects of stimulus intensity on response of auditory nerve fibres in the squirrel monkey. *Journal of Neurophysiology, 29*, 288-314.

Ruben, R. J., Bordley, J. E., Lieberman, A. T. (1961). Cochlear potentials in man. *Laryngoscope. 71*, 1141-1164.

Ruben, R. J., Knickerbocker, G. G., Sekula, J., et al. (1959). Cochlear microphonics in man. A preliminary report. *Laryngoscope. 69*, 665-671.

Ruth, R. A., & Lambert, P. R. (1989). Comparison of tympanic memebrane to promontory electrode recording of electrocochleographic responses in patients with Meneire's disease. *Otolayngology-Head and Neck surgery, 100*, 546-552.

Sass, K. (1998). Sensitivity and specificity of transtympanic ECochG in Meneire's disease. *Acta Otolaryngologica. 118*, 150-156.

Schoonhoven, R., Fabius, M. A. W., & Grote, J. J. (1995). Input/output curves to tone bursts and clicks in extratympanic and transtympanic electrocochleography. *Ear and Hearing. 16*, 6119-630.

Yoshie, N. (1976). Electrocochleographic classification of sensorineural defects: Patholoical pattern of the cochlear compound nerve action potential in man. In R. J. Ruben, C. Elberling, & G. Salomon (Eds.), Electrocochleography (pp. 353-386). Baltimore: university Park Press.

## Acknowledgement

We thank the Director, All India Institute of Speech and Hearing, Mysore for permitting us to conduct the study. We also thank Department of Audiology and all the participants who helped us to successfully complete this scientific paper.