THE EFFECT OF STIMULUS CLICKS ON THE EXTRATYMPANIC ELECTROCOCHLEOGRAPHY IN NORMAL HEARING ADULTS

TEERANUCH ENGKAWISAN

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TEERANUCH ENGKAWISAN: THE EFFECT OF STIMULUS CLICKS ON THE EXTRATYMPANIC ELECTROCOCHLEOGRAPHY IN NORMAL HEARING ADULTS. THESIS ADVISORS: CHEAMCHIT THAWIL, M.A., SIRIPARN SRIWANYONG, M.B.A., M.Sc., MONTIP TIENSUWAN, Ph.D, SAOWAROS ASAWAWICHIANGINDA, MD. 78 P. ISBN 974-665-066-1.

The purpose of this research was to study the effect of stimulus clicks on the extratympanic ECochG. Sixty ears in normal hearing adults(30females, 30males) with ages ranging from 20 to 40 years, served as the subjects. The test instrument used in this study was Smart EP. The stimuli were clicks at 50, 70, and 90dBnHL. The stimulus repetition rates were 7.1/sec and 99.9/sec. The filter setting was 10 to 1500 Hz, and the polarity was alternating.

The results of this study showed that the SP component appeared at the same direction as AP component. There were 2 patterns of AP component waveform. The single peak pattern found was 68.33 %, and the double peak pattern was 31.67%. The mean SP/AP amplitude ratio was 0.1733(SD=.0769). The mean absolute latencies of AP were 1.8403 ms(SD=.1592), and 2.0437 ms(SD=.1978) when 7.1/sec and 99.9/sec click rate stimuli were used respectively, and were significantly different($p<.001$). The mean absolute latency of SP were 0.9770 ms(SD=.0981) and 0.9857 ms (SD=.1021) when 7.1/sec and 99.9/sec click rate stimuli were used respectively, and were not significantly different. The absolute latencies of SP and AP in males and females were not significantly different. The mean ECochG threshold was 34.67 dB (SD=6.36). The ECochG threshold value was significantly higher than the pure tone average threshold($p<.001$). The mean amplitude of AP was significantly increased with increasing intensities($r=.715$, $p<.001$). The mean absolute latency of AP was significantly decreased with increasing intensities($r=-.912$, $p<.001$). At high stimulus intensities(70dB to 90dB), the decrement of AP latency were 0.5665 ms(SD=.4118). At low stimulus intensities(50dB to 70dB), the decrement of AP latency were 0.8705 ms(SD=.5823).

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ธีรนุช อิงควิศาล : การศึกษาผลการทดสอบการตรวจการได้ยินในระดับหูชั้นในและประสาทการได้ยินในผู้ใหญ่ที่มีการได้ยินปกติโดยการกระตุ้นด้วยเสียงคลิกโดยใช้อิเล็คโทรดชนิดใส่ในช่องหูชั้นนอก(THE EFFECT OF STIMULUS CLICKS ON THE EXTRATYMPANIC ELECTROCOCHLEOGRAPHY IN NORMAL HEARING ADULTS) คณะกรรมการควบคุม วิทยานิพนธ์:เจียมจิต ถวิลM.A., ศิริพันธ์ ศรีวันยงค์,M.B.A.,M.Sc., มนต์ทิพย์ เทียนสุวรรณ, Ph.D., เสาวรส อัศววิเชียรจินดา M.D. 78 หน้า. ISBN 974-665-066-1

งานวิจัยครั้งนี้เป็นการศึกษาผลการทดสอบการตรวจการได้ยินในระดับหูชั้นในและประสาทการได้ยิน(ECochG)โดยการกระตุ้นด้วยเสียงคลิก(click)โดยใช้Extratympanic electrode กลุ่มตัวอย่างเป็นผู้ใหญ่ที่มีการได้ยินปกติจำนวน60หู เพศหญิง30หู เพศชาย30หู ช่วงอายุระหว่าง20-40ปี ทำการทดสอบด้วยเครื่องตรวจวัดการได้ยินSmart EP โดยใช้เสียงคลิกทดสอบที่ระดับความดัง 50,70และ90dBnHLอัตราเร็วของเสียงกระตุ้นเท่ากับ7.1ครั้ง/วินาที และที่ระดับความดัง90dBnHL อัตราเร็วของเสียงกนะตุ้นเท่ากับ99.9ครั้ง/วินาที ตัวปรับช่วงความถี่(filter)เท่ากับ10-1500Hz Polarityเป็นAlternate

ผลการศึกษาในครั้งนี้พบว่าคลื่นของSPนั้นไปในทิศทางเดียวกับAPทั้งหมด ที่ระดับความดัง 90dBคลื่นAPพบได้2ลักษณะคือsingle peakพบ68.33% และdouble peak พบ31.67% และอัตราส่วนระหว่างSPกับAPมีค่าเฉลี่ยเท่ากับ0.1733(SD=.07693) เมื่อเพิ่มอัตราเร็วของเสียงกระตุ้นจาก 7.1ครั้ง/วินาทีเป็น99.9ครั้ง/วินาทีที่ความดัง90dBพบว่าระยะเวลาการเกิดคลื่นAPเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ(p<.001) ส่วนระยะเวลาในการเกิดคลื่นSPนั้นไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบระยะเวลาการเกิดคลื่นSPและAPในเพศหญิงและเพศชายไม่พบว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ค่าเฉลี่ยของECochG thresholdมีค่าเท่ากับ34.67dB ซึ่งสูงกว่าค่าเฉลี่ยของPure tone average thresholdเท่ากับ22.80dB(p<.001) ความสัมพันธ์ของความสูงของคลื่นAPกับระดับความดังมีความสัมพันธ์เชิงบวกอย่างมีนัยสำคัญทางสถิติ(r=.715,p<.001) ส่วนระยะเวลาการเกิดคลื่นAPมีความสัมพันธ์เชิงลบเมื่อระดับความดังเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ(r=-.912,p<.001) และยังพบว่าที่ระดับความดังต่ำเมื่อลดความดังจาก70dBไป50dBระยะเวลาการเกิดคลื่นจะลดลงโดยเฉลี่ยเท่ากับ0.8705ms(SD=0.5823) ที่ระดับความดังสูงเมื่อลดความดังจาก90dBไป70dBค่าระยะเวลาการเกิดคลื่นจะลดลงโดยเฉลี่ยเท่ากับ0.5665ms(SD=0.4118)

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CHAPTER I

INTRODUCTION

Statement of The Problem

Electrocochleography (ECochG) is the recording of bioelectric responses of the human cochlea and auditory nerve which is produced or stimulated by sound. These sounds may be clicks, tones and even speech sounds. These responses evoked by the sound are picked up by electrodes, which are usually placed as close as possible to the cochlea. Electrodes used for clinical ECochG are of two basic types: extratympanic, which is placed in the external auditory ear canal, and transtympanic, which penetrates the tympanic membrane to contact the promontory. The record of the potentials recorded via ECochG is called the Electrocochleogram (ECochGm) (1,2). The ECochGm consists of more than one electrical potential which are the eighth nerve compound action potential (AP), the cochlear microphonic (CM), and the summating potential (SP).

The AP is an alternating current (AC) potential. The AP is an algebraic sum of the action potentials from the spiral ganglion and cochlear nerve (3). The AP component is also referred to as "N1." It is the same auditory response as the ABR wave I component (4).

The CM is an alternating current (AC) potential that follows the waveform of the stimulus. The CM arises from hair cells and in the normal cochlea at least

mainly from outer hair cells (5,6). When recorded from outside the cochlea, the CM reflects outer hair cell activity in the basal portion of the basilar membrane. Mechanisms underlying CM production are not clearly defined, and they may involve velocity or acceleration of hair cell movement and displacement of the basilar membrane (4).

The SP is a Direct current (DC) potential that can be observed as a baseline shift in the CM. The precise source of the SP within the cochlea is unknown. It has been attributed to distortion products associated with irregularities in basilar membrane and hair cell displacement, and subsequent generation of electrical current and to both inner and outer hair cells activity (4,5,7).

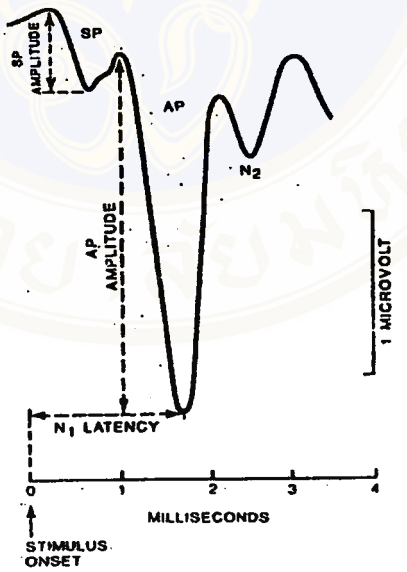

Figure 1. Electrocochleographic response to click stimuli recorded from the ear canal(11).

ECochG has mainly been applied in the diagnosis of endolymphatic hydrops (ELH). In hydropic ears, the basilar membrane is distended towards the scala

tympani and this may be the reason for the enlarged SP in ELH. Many investigators agree that specific changes of the AP and SP , as well as the SP/AP ratio, are correlated with the presence of ELH (3). The finding of an abnormal SP/AP amplitude ratio has been widely regarded as the most valid variable in ELH (8). In many reports, a relationship between an increased amplitude of the SP and a hydropic condition has been mentioned (9). The summating potential to action potential (SP/AP) ratio, is repeatedly elevated and is a specific indicator without being extremely sensitive (10).

ECochG is used in clinics for the past several years and provides information in the area of audiology and otology. The purposes of using ECochG in clinics are :

1. to evaluate peripheral auditory system and related pathology.
2. to evaluate the cochlea and eighth nerve.
3. to evaluate patients with Meniere's disease (i.e., endolymphatic hydrops.)
4. to enhance ABR Wave I for differentiate cochlea and retrocochlear pathology.
5. to estimate hearing threshold.
6. to monitor the cochlea and eighth nerve status intraoperatively during posterior fossa surgery (11,12,13,14).

Attempts at clinical applications of ECochG date back almost as far as the discovery of the cochlear potentials by Wever and Bray (15) , but practical

applitions were not realized until the late 1960s. The clinical used of ECochg were decreased over the next decade because transtympanic needle ECochG electrodes were used. The relatively invasive nature of these electrodes limited clinical application of ECochG. Although transtympanic EcochG provides better electrical response when the recording electrode is close to the hair cells , but due to the discomfort experienced by the patient and the need of assistance of a well trained physician, this technique has not gained widespread acceptance among audiologists. Therefore, several electrode sites have been used partly to simplify the procedure. Usual electrode placement is in contact with the ear drum or the ear canal, which can be done without direct assistance of a physician and noninvasive technique. This eliminates pain or discomfort to the patient, the information presented in this research will pertain to the use of noninvasive, extratympanic recording technique (16,17). At Ramathibodi hospital, extratympanic ECochG is one of the objective instrumentation used to begin in the Speech and Hearing Clinic to evaluate Meniere's disease patient. At present, there are no normative data utilizing extratympanic ECochG in Thailand. Therefore, it is necessary for the audiology unit to have its normative data for assessing the cochlea and auditory nerve. From the above mentioned reasons, the researcher attemps to study the effect of stimulus clicks on the extratympanic electrocochleography in order to establish normative data in normal hearing adults.

The Purpose of This Research

1. To study the ECochG waveform morphology in normal hearing adults when TIPtrode are used at 90 dB.

2. To study the mean absolute latencies of SP and AP in normal hearing adults when click stimulus of 90 dBnHL.

3. To study the mean amplitude ratio of SP/ AP in normal hearing adults when clicks stimulus of 90 dBnHL.

4. To compare absolute latencies of SP, AP in normal hearing adults when different stimulus repetition rate 7.1/sec and 99.9/sec on clicks ECochG are used at 90 dBnHL.

5. To compare absolute latencies of SP, AP in normal hearing male and female adults when different stimulus repetition rates 7.1/sec and 99.9/sec on clicks ECochG are used at 90 dBnHL.

6. To compare clicks ECochG threshold and pure tone average threshold in normal hearing adults.

7. To study the amplitude-intensity and latency-intensity function in normal hearing adults.

The Hypothesis of This Research

1. The mean absolute latencies of SP and AP are significantly different in normal hearing adults when different stimulus repetition rate 7.1/sec and 99.9/sec are used.

2. The mean absolute latencies of SP and AP in normal hearing male adults are significantly different from those of the normal hearing female adults when different stimulus repetition rate 7.1/sec and 99.9/sec are used.

3. The clicks ECochG threshold are significantly higher than the pure tone average threshold.

4. The absolute latency is decreased when intensity is increased but the amplitude is increased when intensity is increased.

The Expected Outcomes of This Research

1.The result of study can be used as a normative data of Extratympanic ECochG in normal hearing adults.

2. The result of study can be employed to evaluate whether the pathology is located at cochlear or retrocochlear.

3.The result of study can be used to estimate hearing threshold in difficult to test patients.

CHAPTER II

LITERATURE REVIEW

Electrocochleography (ECochG) has become and important tool in the identification , assessment , and monitoring of certain otological and audiological disorders. In general, ECochG is a method of recording the stimulus-related potentials of the peripheral auditory system. The specific responses recorded may include the cochlear microphonic (CM) and components of the summating potential (SP) of the cochlea, and the whole-nerve or compound action potential (AP) of the auditory nerve.

It is generally acknowledged that the first recording of human CM was reported by Fromm et al. (18) In 1935, although several features of both the CM and the auditory nerve AP had been described based on animal studies before this time. By 1950, the CM had been recorded by numerous other investigators using electrodes on or near the round window of subjects undergoing ear surgery (19). The human auditory nerve AP was first recorded by Ruben and his co-workers (20) in 1960, also during ear surgery.

Perhaps the most significant factor in the development of clinical ECochG to the current era was the application of signal averaging techniqes, which allowed for nonsurgical recordings (21). Yoshie et al. (22) initiated extratympanic recordings using subdermal, ear canal electrodes, whereas Portmann and Aran (23)

utilized a transtympanic approach with the primary electrode seated on the promontory.

In the 1970s, ECochG received comparatively little attention as a clinical tool, especially in the United States. Recently, however, there has been a renewed interest in the clinical application of this technique, and many laboratories and clinics engaged in evoked response testing are beginning to utilize ECochG once again (12).

The use of ECochG for clinical purpose involved the basic knowledge of anatomical origin of ECochG, waveform parameter, affecting factors and clinical application of EcochG. These factors are reviewed as follow:

1. Anatomical origin of ECochG

The cochlear potentials of interest in clinical practice include the cochlear microphonic (CM), the summating potential (SP) and the compound action potential (AP) of the auditory nerve (4,24). Figure 2 shows important structures within the cochlea.

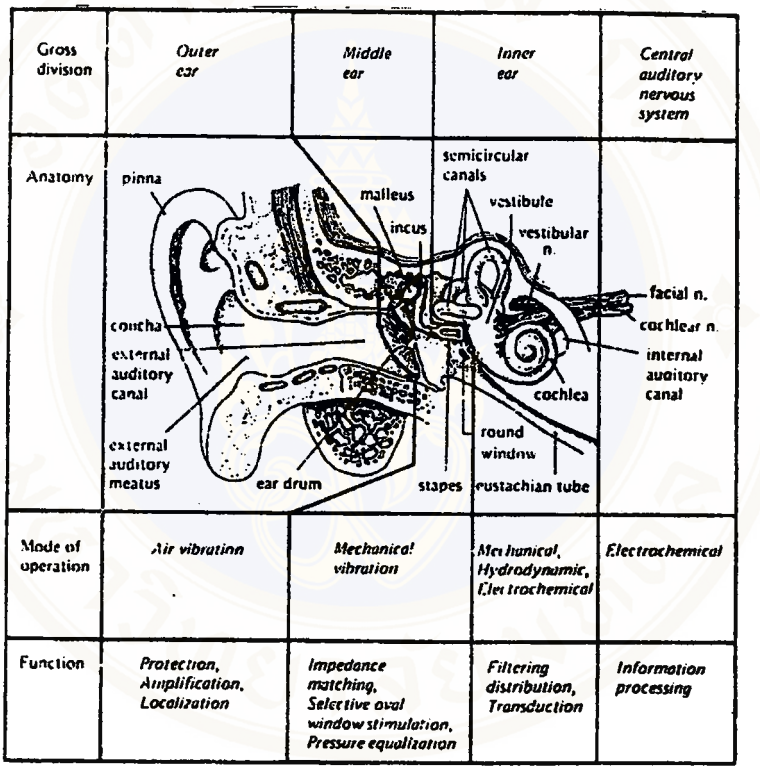

Figure 2. Schematic representation of the peripheral auditory system, including outer ear, middle ear, inner ear and distal portion of the eight cranial nerve. Below are listed the predominant modes of operation of each division and its suggested function. *Note.* From Fundamental of Hearing: An Introduction (p.62) by Yost WA (25).

1.1 The Cochlear microphonic

Wever and Brey (16) were the first to describe the cochlear microphonic (CM) in an animal model. The CM is an alternating current (AC) potential that occurs only during the presentation of an acoustic stimulus, generating at the hair-cell level in the cochlea (4,26,27). The CM has a similar waveform to the stimulus (2). The CM has no latency because it begins with the stimulus. The CM arises from hair cells, and in the normal cochlea at least, mainly from outer hair cells (5,6). When recorded from outside the cochlea, the CM reflects outer hair cell activity in the basal portion of the basilar membrane (28). Mechanisms underlying CM production are not clearly defind, and they may involve velocity or acceleration of hair cell movement and displacement of the basilar membrane. Single polarity (rarefaction or condensation) stimuli are most effective for eliciting the CM, whereas alternating these stimulus polarities effectively cancels out the CM (4).

1.2 The Summating Potential

This cochlear potential was first described in two independent investigations by Davis et al. (29) and Bekesy (30). Unlike the CM, the SP is a direct current potential. The SP may be viewed as a complex multicomponent response representing the sum of various nonlinearities associated with cochlear processing (31). The SP tends to follow the envelope (i.e., on-off pattern) of the stimulus, rather than in waveform (5).

The SP has received a good deal of attention in recent years for its application in the assessment of Meniere's disease. The amplitude of the SP is often enlarged in patients with endolymphatic hydrops, particularly as compared to AP amplitude (32) . The reason for this finding is still unclear, but may reflect increased asymmetry in basilar membrane movement or increased nonlinearity in hydropic inner ears (33). In any event, it is well established that an enlarged SP may be pathognomonic of Meniere's disease (27).

1.3 The Action Potential

The whole-nerve or compound action potential of the auditory nerve was first recorded in humans undergoing ear surgery by Ruben et al. (20). The AP represents the most popular stimulus-related potential measured by means of ECochG in humans. When using conventional ECochG electrodes, the AP reflects the summed response of synchronous discharges from several thousand individual nerve fibers primarily located in the basal or high frequency region of the cochlea (34) . As with the CM, the AP is represented as an alternating current voltage. The waveform of the AP is characterized by a relatively large negative deflection referred to as N1. This component (N1) is identical to wave I of the surfaced recorded ABR. Both N1 of the ECochG and wave I of the ABR arise from the distal portion of the auditory nerve (35).

2. ECochG Parameters

2.1 Waveform morphology

Morphology refers to the visual appearance of the waveform. Morphology is a subjective parameter in ECochG measurement because it cannot be specified in measurable units such as milliseconds or microvolts. Several investigators have observed that some component of ECochG morphology are often varied when different stimulus repetition rate were used.

Staller (36) suggested rate of stimulus presentation also has a significant impact on ECochG recordings. As a neural response, the AP begins to demonstrate amplitude reduction due to adaptation at stimulus rates exceeding approximately 15/sec. The rapid rate fatigues the AP, leaving only an intact SP, which as a hair cell receptor potential does not have a measurable refractory period. Ferraro and Ruth (32) found increasing repetition rate beyond 30/sec may cause some adaptation of the AP. Rates on the order of 100/sec will cause maximal depression of the AP, while leaving the SP relatively unaffected. Mouney et al (37) suggested CM and SP components of ECochG remain relatively stable over a wide range of stimulus rates. In contrast, latency of the AP component increases and amplitude decreases as rate increases to over 100 clicks/sec. The basis may be desynchronization at the cochlear level perhasps an adaptation phenomenon at the synapse between hair cells and auditory nerve afferents (40).

2.1 Response amplitude and amplitude ratio

The amplitude of ECochG is refered to the height of SP and AP peak component. The amplitude is usually described in microvolts (μV). The difference between peak voltage of the wave and some measure of baseline voltage is calculated to obtain the ratio of SP and AP peak component (4). Yen PT et al. (8) reported that AP amplitude was measured from the baseline to the point of maximum deflection of AP (N1 peak) and SP amplitude was measured from the baseline to the notch on the ascending limp of AP for a click stimulus.

Several investigators found, absolute SP amplitude varied depending on measurement parameters, especially the recording electrode sites (39,40,41,42). Amplitude of the CM the SP and the AP does increase with intensity, and its amplitude directly reflects stimulus intensity. Rate of amplitude change in normal subjects is on the order of 0.5-1.0 % for intensity levels up to 60 dB and then increases to 1.0-3.0 % above 60 dB (5,43). The ECochG data from numerous studies on patients suspected of endolymphatic hydrops support that there is an enhanced SP component (33,41,45). The amplitude of the SP is often variable and Eggermont has suggested that the SP be expressed as a percentage of the AP to reduce the across-subjects variability (46). Ferraro (1986) suggested normal values of SP/AP amplitude ratio in his laboratory (ET ECochG) range from approximately 0.1-0.5, with a mean of approximately 0.25. In addition, Coat et al.(1984) studied in normal subjects by ET ECochG. They found normal SP/AP amplitude ratio is only 25 percent (0.25). Mori et al. (47) studies the role of summating potential in the diagnosis

and management of Meniere's disease in 70 patients with unilateral Meniere's disease. The click-induced SP and AP were recorded by extratympanic electrocochleography. They found when SP/AP ratio exceeded 0.43 the SP was considered to be abnormal. Daniel et al. (45) studies the SP and AP potential ratio in Meniere's disease before and after treatment in 88 ears of 84 patients with Meniere's disease. Transtympanic ECochG was performed in all patients before and after treatment. The results showed that the distribution of and enlarged SP:AP ratio was associated with the duration of disease. The longer the duration of the disease, the more likely the SP : AP ratio will be enlarged.

In the past, both AP and CM were considered useful for detecting endolymphatic hydrops (48, 49) but it now seems that the SP is more reliable for such a purpose. In many reports, a relationship between and increased amplitude of the SP and a hydropic condition has been mentioned (41,50). Mori and colleagues studied in 70 patients with unilateral Meniere's disease, they found that the click-induced SP was better at reflecting the patho-physiology of Meniere's disease at the high-frequency cochlear partition, i.e. at the basal cochlear turn (51).

An increased SP amplitude has often been found in cases of sudden deafness (52,53,54), suggesting a close relationship between sudden deafness and hydrops. Nishida and Kumagami (52) described different ECochG findings between cases with complete or marked improvement and those with slight or no improvement;

they also stressed the prognostic value of ECochG results in early diagnosed sudden deafness.

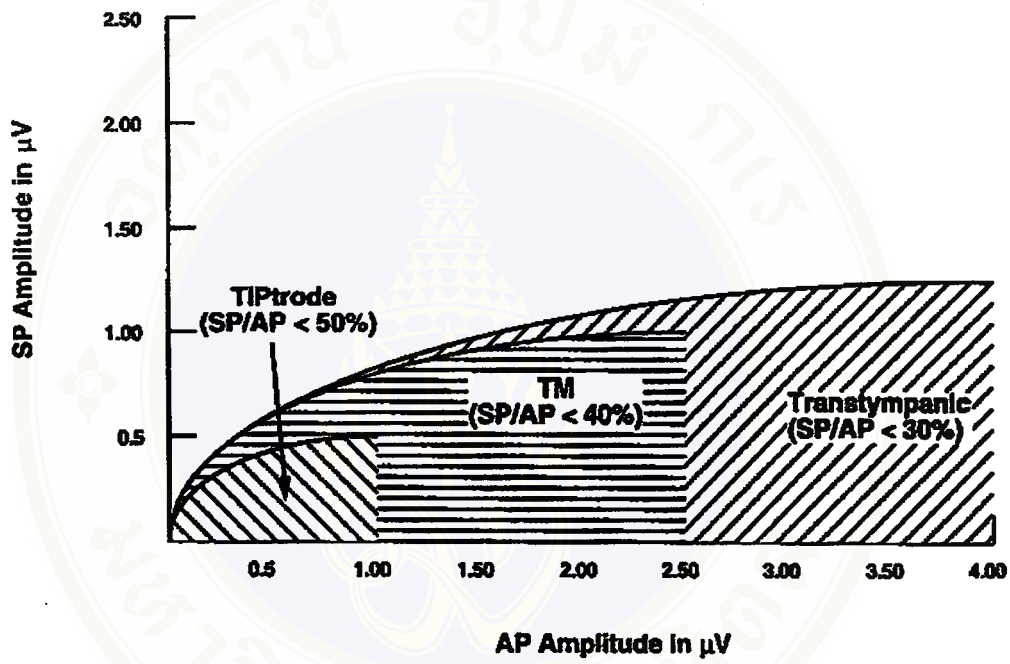

Figure 3 presents the relation of SP versus AP amplitudes for three different types of ECochG electrodes (13).

2.2 Response Latency of individual SP and AP

The latency of ECochG is the time interval between the exact moment of stimulus presentation and the appearance of a change in SP and AP waveform. Latency is expressed in milliseconds (msec). The AP was measured from the alternating polarity click response as the difference between the prestimulus baseline and the maximum negative deflection. Similary, the SP was measured

from the prestimulus baseline to the "knee" on the leading edge of the AP. The AP latencies were measured as the poststimulus onset time at which the largest negative deflection occurred (7).

Numerous investigations and years of clinical experience have shown that latency of ECochG AP systematically decreases as stimulus intensity increases (1,4,12). The latency shift as a function of intensity is relatively greater for low stimulus frequencies. One factor in the latency-versus-intensity relationship is the site of cochlear activation. Higher intensity levels activate more basal (high frequency) portions of the cochlea, while lower intensity levels activate more apical portions. The time delay from stimulus onset is shorter for basal versus apical cochlea activation because travel time along the basilar membrane is less. This factor is involved in both intensity-versus-latency and frequency-versus-latency interactions.

Another factor is synaptic delay. This delay is less with high than with low stimulus intensity levels. The latency changes due to synaptic delay are equivalent for all stimulus frequencies. One important principle of ECochG measurement, especially for audiometric assessment, is evident from these comments. Frequency specificity in ECochG generation is greatest for lower intensity levels and is reduced for higher stimulus intensity levels (4).

3. Factors affecting ECochG Parameters

3.1 Stimulus intensity

Stimulus intensity also influences ECochG component clarity both latency and amplitude. Response latency of ECochG component is decreased as stimulus intensity is increased; whereas response amplitude of ECochG component is increased as stimulus intensity is increased (5,25,39,40,55,56,57). AP latency decreases slightly, and amplitude increases markedly as stimulus intensity is increased. The SP is not observed at lower intensity levels (usually below 60 dB peSPL) (4,25). One factor in the latency-versus-intensity relationship is the site of cochlear activation. Higher intensity levels activate more basal (high frequency) portions of the cochlea, while lower intensity levels activate more apical portions. The time delay from stimulus onset is shorter for basal versus apical cochlea activation because travel time along the basilar membrane is less. The SP is typically recorded only at high stimulus intensity levels (58,59). The normal human SP is first detected at a click intensity level of about 92 dBSPL (approximately 62 dBnHL) and then amplitude gradually increases as click intensity level increases (40,57,60). SP variability extends, naturally, to the SP/AP relation as well and to changes in the SP/AP relation with intensity (4). Ferraro (11) suggested ECochG should be tested at adequately high intensity to provide a well-defind SP-AP complex. He began stimulus presentation at the maximum dB output of signal generator (95 dBHL) at a rate of 9-11 / sec. Inaddition, Ferraro and Ruth (61) began stimulus presentation at a level near or at the maximum output of the

stimulus generator (85-95 dBnHL). The reason for this is that when the ECochG is performed to help diagnose Meniere's disease, the signal should be intense enough to evoke a well-defind SP-AP complex.

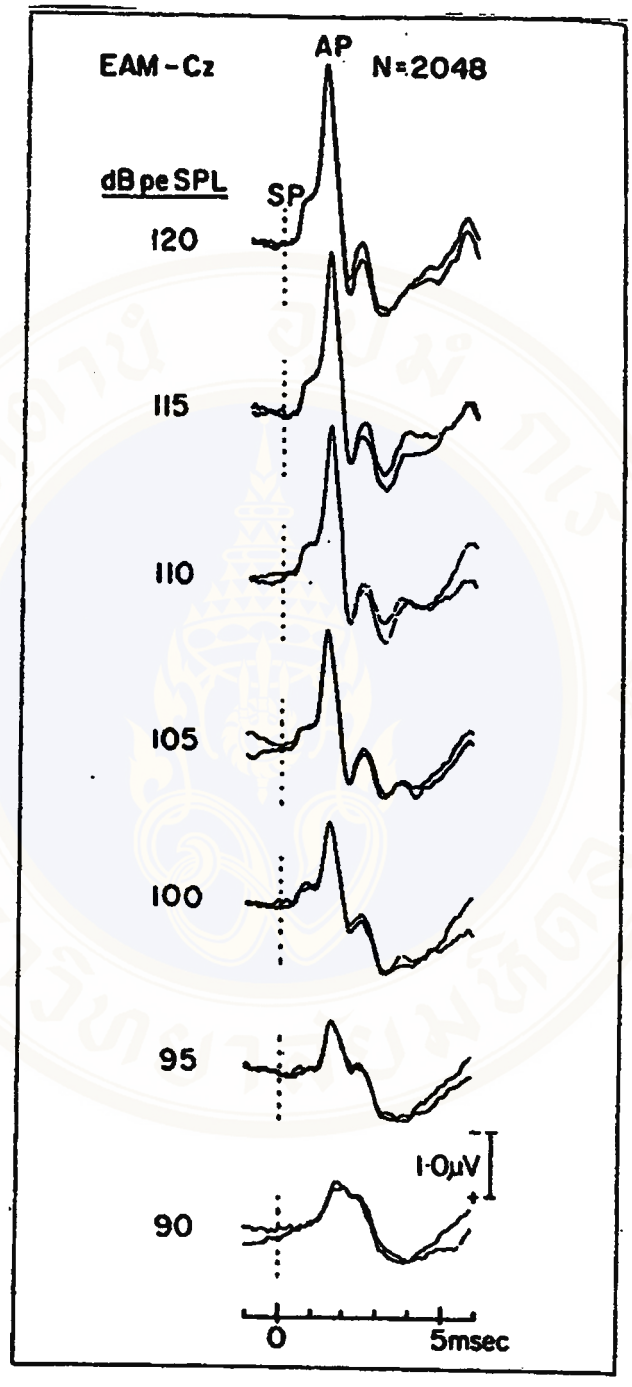

Figure 4. ECochG waveforms as a function of click stimulus intensity level (4).

3.2 Stimulus polarity

Stimulus polarity is referred to the initial direction of the pressure wave front in the stimulus waveform measured at the face of the transducer. There are three categories of stimulus polarity in ECochG measurement – condensation, rarefaction, and alternating. Stimulus ECochG polarity effects in the cochlea and the eight nerve have been demonstrated experimentally recording in animal. Some investigators reported rarefaction polarity stimuli presented at moderate or high intensity levels, as expected, produced eight-nerve activity that preceded condensation-elicited activity (62,63). Margolis et al. (7) reported when using condensation and rarefaction clicks, occasionally the CM was so large as to obscure the AP. When it was not possible to clearly distinguish between the CM and the AP, the alternating polarity were used instead. Gerull et al. (64) suggested AP latency is considerably earlier (0.6 msec) for rarefaction versus for condensation polarities. Ferraro and Ruth (61) reported that clicks in alternating polarity would help to inhibit the presence of stimulus artifact and CM in the resultant waveform. On the other hand, Margolis and Lilly (65) have presented evidence that separate responses to condensation (C) and rarefaction (R) clicks may provide useful clinical information. Separate R and C responses may also be added together "off-line" to reduce CM and stimulus artifact. When the CM follows polarity of a click stimulus, summing or averaging the response to stimuli of alternating polarity will generally cancel out the CM (66).

3.3 Stimulus repetition rate

The stimulus repetition rate is the number of click stimuli presented per unit time (one second). The stimulus repetition rate affects the component of ECochG parameter, but the changing is not the same for each component. CM and SP components of ECochG remain relatively stable over a wide range of stimulus rates. In contrast, as shown in Figure 6, latency of the AP component increases and amplitude decrease as rate increases to over 100 clicks/sec (4,37,57). The basis may be desynchronization at the cochlear level and perhaps adaptation phenomenon at the synapse between hair cells and auditory nerve afferents (67).

The ECochG SP component is reportedly independent of stimulus rate, but amplitude for the AP component diminishes as rate increases. Therefore, a relatively slow rate (e.g., 5.1 or 7.1/sec)is recommended for ECochG to enhance AP identification and to ensure more reliable SP/AP calculations (4). In addition, Ferraro and Ruth (61) found click rates between 5-11/sec to be most suitable for well-defined responses within a reasonable testing time. Increasing repetition rate beyond 30/sec may cause some adaptation of the AP. Rates on the order of 100/sec will cause maximum depression of the AP, while leaving the SP relatively unaffected.

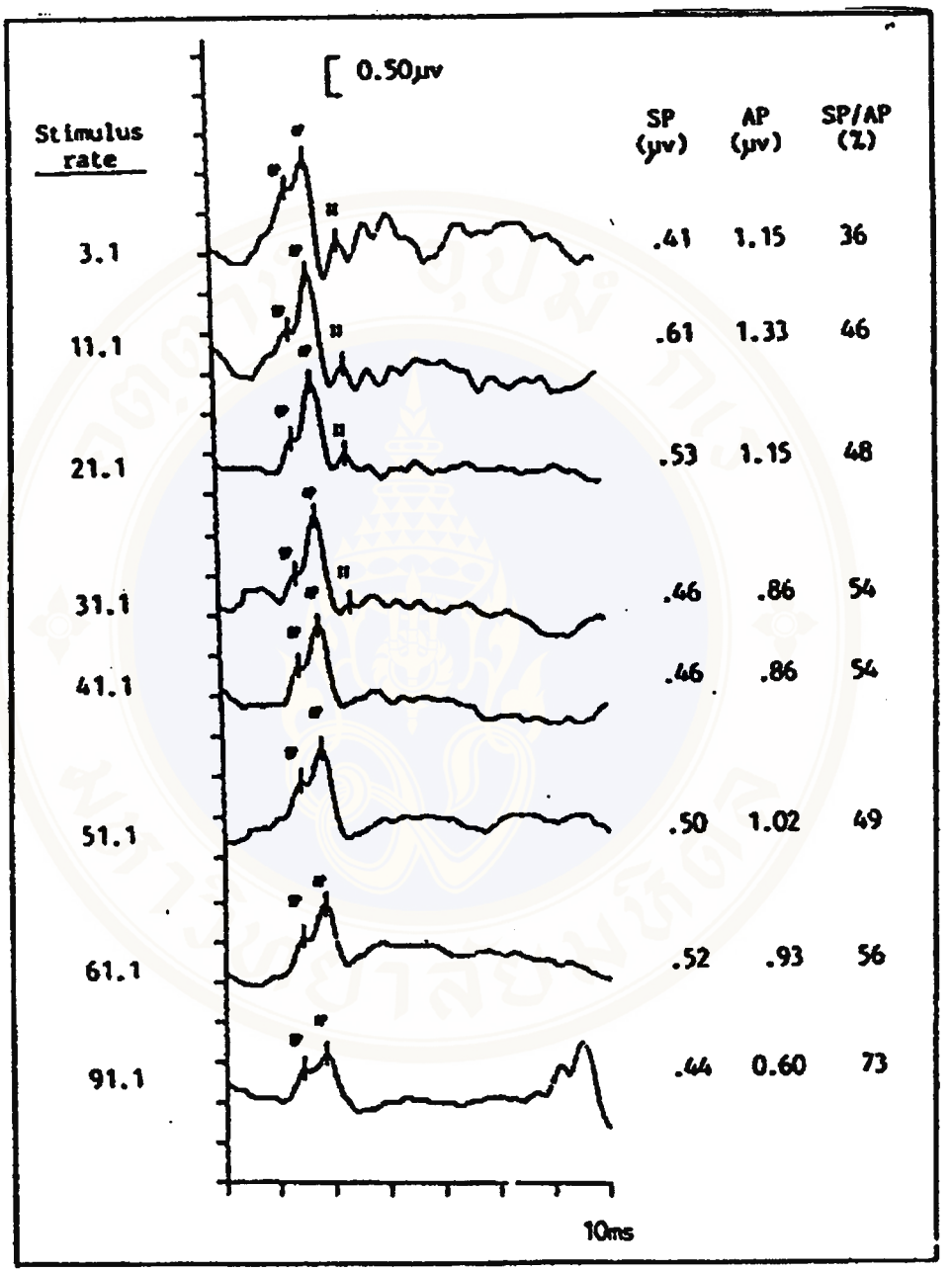

Figure 5. ECochG waveforms illustrating differential effect of rate on SP versus AP (4).

3.4 Electrode placement

A variety of electrode locations have been employed to record cochlear potentials in animal and human investigations. In animal studies, electrodes are commonly placed in the cochlea, on the round window, or directly on the auditory nerve. In humans, three electrode sites have been employed. Transtympanic ECochG is performed by placing a needle electrode through the tympanic membrane and onto the promontory (48,68). Tympanic ECochG employs an electrode placed on the tympanic membrane (69,70). Extratympanic ECochG is performed with an electrode that is placed in contact with the ear canal wall (71,72).

Although the list of general problems that may develop in ECochG recording is long, many can be solved with optimal electrode placement. ECochG activity arising from the cochlea and distal (cochlear end) eight nerve is best measured with a near-field technique. As the recording electrode approaches the cochlea, response amplitude increases dramatically. For a normal ear, ECochG SP or AP components detected with a promontory electrode (resting on the outer wall of the cochlea) are from 10 to as much as 20 times larger than those detected with an electrode located in the ear canal (4). Because the promontory electrode site is close to the ECochG generators (the cochlea and eighth nerve), the ECochG recorded with this electrode array is a near-field responses, and the SP and AP components are typically large and easy to detect, even at low intensity levels and with minimal averaging (73). The clinical limitation of the technique, however, is

clear. Reliance on a TT electrode renders ECochG and invasive procedure that cannot be carried out by most non surgeon clinicians (73,74).

Absolute SP amplitude varied, depending on electrode sites. For example, with an external auditory meatus electrode, average SP amplitudes is lower than with a promontory electrode site (40,60,75) The SP/AP amplitude ratio (in %) varies depending on the electrode site relative to the cochlea. An electrode closer to the cochlea produces a smaller ratio than an electrode relatively farther from the cochlea (13).

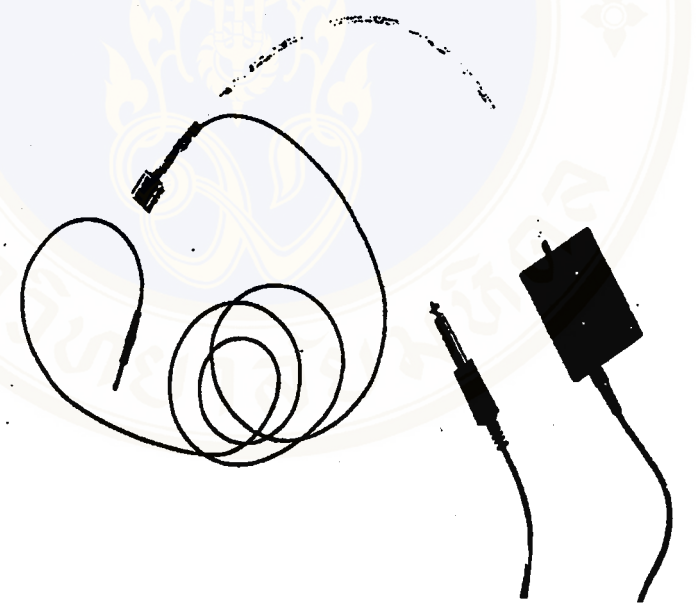

Figure 6. TIPtrode electrode design with electrode wire and acoustic transducer (insert tubephone) (4).

3.5 Subjects parameters

3.5.1 Age

Several investigators attemped to study the effect of age in ECochG. Hall (4) suggested ECochG in essentially mature at term birth, although development of cochlear function before term in infants may directly influence ECochG measurement. Chatrian et al. (76) found age-related differences were observed, but not consistently for each response parameter. SP detection level (in dB) was positively correlated with age (higher intensity was required to detect a response in older subjects), while SP amplitude decreased as a function of age, yet only for the left ear. There was a strong negative correlation between AP amplitude and age and, as a result, a positive correlation between the SP:AP ratio and age. With advancing age, AP amplitude decreased relatively more than SP amplitude, resulting in an increase of the SP:AP ratio with age advancement. Schwartz et al. (77) provided evidence that CM and SP components can be consistently recorded even in preterm newborns. They also found that the presence of CM and SP was support for the notion that the cochlea was electrically mature in newborns. Since aging effects almost every aspect of auditory system, including cochlea and eighth-nerve function, it would not be unreasonable to expect age-related changes in CM, SP, and AP components of the ECochG (4). A clear ECochG N1 component is normally recorded as early as 27 weeks' conceptional age. In comparison to adult values, latency is prolonged and amplitude reduced (78).

The main objective of most ECochG studies is to assess the relation between ECochG and behavioral hearing threshold levels, rather than to examine waveform characteristics (e.g., CM, SP, and AP) as a function of age. Threshold for ECochG and behavioral testing may be within ± 10 dB in normal hearing subjects, hearing-impaired children, and adults with high-frequency sensori neural loss, when transtympanic recordings are made (40,57,79,80,81,82). The ECochG can be reliably recorded from normal hearing infants and young children contributed to the early interest in this technique for "objective" assessment of hearing function in this population (40,79,83,84,85).

3.5.2 Gender

Some investigators have reported no gender different in newborns (86). Others found shorter latency in female versus male preterm infants, but the differences were small and inconsistent in comparison to the striking gender effect for adults (87). Chatrian et al. (88) recorded no significant difference between male versus female adults for detectability of the SP, the SP onset time, or the SP peak latency; nor was there significant difference for the duration of the SP-AP complex. SP amplitude, on the other hand, was significantly larger for females than for males. Significantly larger AP amplitude was consistently recorded for females versus males, yet the SP:AP ratio was equivalent between sexs. Coats (1) reported a tendency for greater SP and especially AP amplitude for women versus men.

Several investigators (86,89,90) have found females show shorter latency values and larger amplitudes than males for later ABR waves (III, IV, V, and VI), but the effect is negligible for wave I or compound AP potential of ECochG.

3.5.3 Muscular artifact

Muscular and movement artifact is a major source of unwanted noise in the recording of ECochG and can seriously reduce the signal-to-noise ratio. A quiet patient state contributes to less background noise and facilitates detection of even a small amplitude response. Random movement-related artifact may confound ECochG interpretation, especially identification of the SP component. The SP often appears as a hump on the upward slope of the AP. False identification of the SP is more likely when excessive movement artifact is present in the waveform, particularly without strict criteria for reliability. As with ECochG, muscle artifact may be mistaken for wave components (4,23,26).

4. Clinical Applications

Several studies have now shown that ECochG can contribute significantly to the identification, assessment, and monitoring of certain audiologic, otologic, and neurologic disorders. More specifically, the currently most common clinical applications of ECochG include:

1. the objective identification and monitoring of Meniere's disease and endolymphatic hydrops; Probably most attention with regard to the clinical

application of ECochG has been focused on the evaluation and monitoring of Meniere's disease or endolymphatic hydrops (32,91). Electrocochleography is employed to evaluate cochlear function in patients with symptoms associated with Meniere's disease is widely suspected to be endolymphatic hydrops, which has been shown in animal studies to systematically alter cochlear potentials (92). Margolis (7) studied Tympanic Electrocochleography for diagnosis of Meniere's disease. The subjects were 53 normal hearing adults, with negative histories for symtoms of Meniere's disease. He found the normative data presented in this article are useful for the detection of Meniere's disease in its early stages. Other investigator recorded, clinical applications of ECochG can be use of the enlarged cochlear summating potential (SP) to detect endolymphatic hydrops (1). Yen PT et al. (8) reported in recent years, the use of ECochG in the detection and monitoring of endolymphatic hydrops and Meniere's disease has become enormously popular since the introduction of non-invasive extratympanic recording technique.

The SP has received a good deal of attention in recent years for its application in the assessment of Meniere's disease. The amplitude of the SP is often enlarged in patients with endolymphatic hydrops, particularly as compared to AP amplitude (32) . The reason for this finding is still unclear, but may reflect increased asymmetry in basilar membrane movement or increased nonlinearity in hydropic inner ears (33). In any event, it is well established that an enlarged SP may be pathognomonic of Meniere's disease (27).

2. the enhancement of wave I and the identification of the I-V Interwave Interval (IWI) of the ABR in the presence of hearing loss or less than optimal recording conditions: ECochG does have clinical uses enhancement of wave I in patients with substantial hearing loss (32,91).

3. the monitoring of cochlear and auditory nerve function during surgical procedures that place the ear at risk for permanent damage: ECochG does have clinical uses in the intraoperative monitoring of peripheral auditory structures at risk for damage secondary to surgically induced trauma (32,91).

4. the seeking of hearing threshold : new generation of ear-canal electrodes has contributed to a marked increase in clinical investigation of ECochG in assessment of auditory threshold levels (12,93). Wong (94) suggested ECochG can be used in conjunction with other audiometric methods for threshold estimations in the difficult-to-test children and as part of the preoperative assessment for cochlear implantation.

CHAPTER III

MATERIALS AND METHODS

1. Subjects

Sixty ears of normal hearing adults were used as the subjects for this study. The age ranged from 20-40 years. There were 30 male's ears and 30 female's ears. The inclusion criteria for normal subjects consisted of :

1. no outer and middle ear disease.
2. no hearing loss , tinnitus and vertigo.
3. normal pure tone audiogram (hearing threshold levels of 25 dBnHL or better) at all tested octave frequencies from 250 to 8000 Hz.
4. normal type A tympanogram with presence of stapedias acoustic reflex both ipsilaterally and contralaterally.

All subjects received otoscopy and routine audiologic evaluation. Otoscopy were performed to examine the status of the outer ear and the tympanic membrane of the subjects. A routine audiologic evaluation which consisted of pure tone air-conduction tested at the octave frequencies of 250 to 8000 Hz, tympanometry and stapedius acoustic reflect testing at 500, 1K, 2KHz ipsilaterally and 500, 1K, 2K, 4KHz contralaterally.

2. Instrumentation

The instrumentations used in this research are the following :

1. Otoscope
2. Audiometer – Beltone 2000
3. Acoustic Immittance Instrument – GSI 33
4. Electrocochleography instrument – Smart EP
5. Insert ear phone – ER-3A

3. Procedures

All subjects were instructed to rest in the supine position on the bed. This condition was to minimize postural muscle activities in neck and head. The testing was conducted in the sound treated room. Special care was taken in preparing the subject ' s skin for electrode placement. Alcohol 70% and skin prep were used to clean the skin where the electrodes placement on forehead and both mastoid, alcohol 70% was used to clean in the ear canal. The reference electrode cup was placed on the nontested mastoid (A1 or A2) and active disposable foam plug gold foil electrode was insert in the outer test ear canal (A1 or A2). A common electrode cup was placed on the forehead (Cz). An electrolyte cement and electrolyte gel were applied to improve the conductivity of the skin , to give contact stability and to effectively increase the electrodes surface area. Electrode impedances were maintained below 7000 ohms.

The Smart EP was used to record the subject ' s ECochG responses. First record on the right ear, the stimuli were clicks with 100 μsec duration. The polarity of the clicks was alternate. The bandpass of the clicks was 10 to 1500 Hz. Stimuli were presented at the rates of 7.1 and 99.9/sec. First clicks rate 7.1 / sec was presented at 90 , 70 , 50 , 30 and 10 dBnHL. Then 99.9 /sec clicks rate was presented at 90 dBnHL. Each trial consisted of 1000 – 2000 sweeps per average. For ECochG measuring , the tested ear was stimulated ipsilaterally. Each clicks rate was recorded three times to ensure the repeatability of the waveforms. Second record on the left ear is used at the same procedure. The responses were printed paper for later analysis. Absolute latencies of SP, AP, waveform morphology and amplitude of waves were identified by two advisors and the researcher. The final agreement was based on the decision made by two examiners.

4. Data Analysis.

The following statistical methods were employed to analyze the obtained data :

1. Mean and standard deviations (S.D.) were used to study the absolute latencies SP, AP and SP/AP amplitude ratio.

2. Paired t-test was used to compare differences in absolute latencies SP, AP between stimulus repetition rate 7.1/sec and 99.9/sec, to compare clicks ECochG threshold and pure tone average threshold, and to compare AP latency between stimulus intensity 90 dB, 70 dB, and 50 dB.

3. T-test was used to compare differences in absolute latencies SP, AP between male and female.

4. Pearson's correlation coefficient was used to study the relationship between amplitude-intensity function and latency-intensity function.

CHAPTER IV

RESULTS

The purpose of this study was to investigate ECochG recordings of sixty adult's ears with normal hearing. There were 30 female's ears and 30 male's ears. The age of subjects ranged from 20 to 40 years. The mean age was 30.40 years and the standard deviation was 5.63. The data were collected in the Speech and Hearing Clinic at Chulalongkorn hospital. The raw data of latencies and amplitude ratio of SP, AP were shown in Appendix. The results of the study were analyzed into the following categories :

-waveform morphology

-the absolute latencies of wave SP, AP

-the amplitude ratio of SP/AP

-the click ECochG threshold and pure tone average threshold

-the amplitude-intensity and latency-intensity function

1. ECochG waveform morphology when TIPtrode at 90 dBnHL were used in normal hearing adults.

From this study, SP component of ECochG morphology showed same direction as the AP component. The AP morphology appeared as a single peak pattern and as a separate peak pattern. The single peak pattern was 68.33 %, and the separate peak pattern was 31.67 % when conventional stimulus repetition clicks rate were used. At high stimulus repetition clicks rate, the AP latency increased and amplitude decreased, while leaving the SP relatively unaffected. The ECochG waveform morphology were illustrated in figure 7.

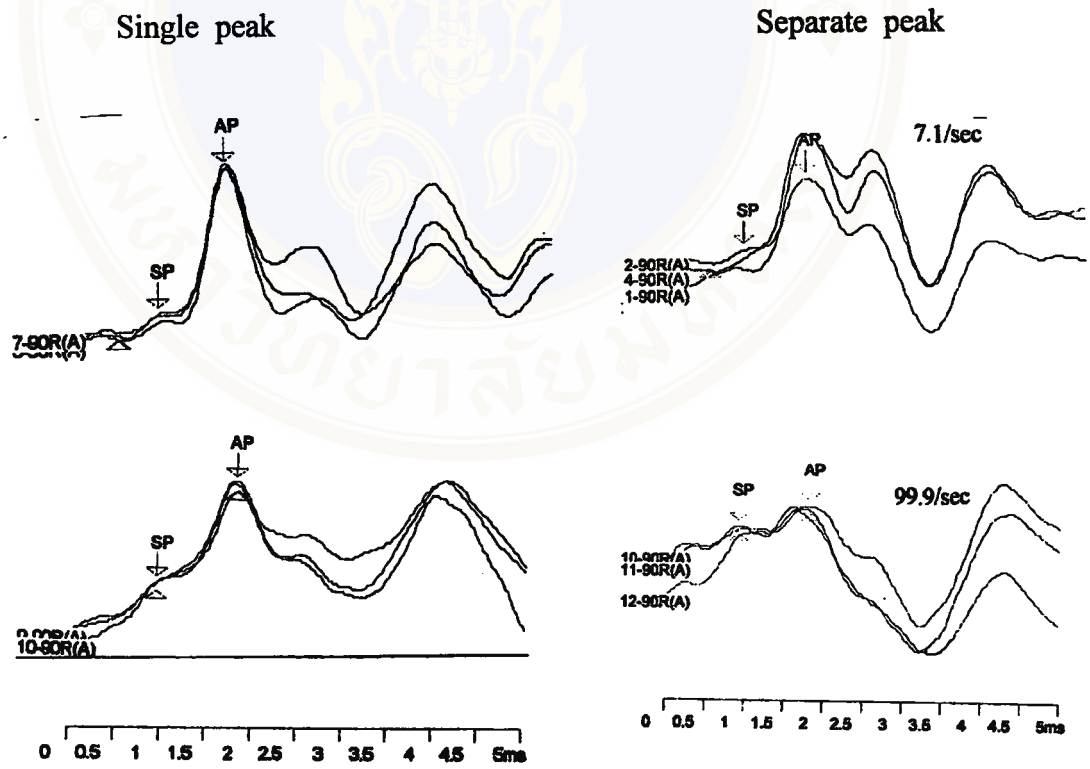

Figure 7 Examples of ECochG recordings obtained using TIPtrode from normal hearing adult subjects.

2. The absolute latencies of SP and AP when stimulus click rate 7.1/sec at 90 dBnHL were used.

Table 1 showed the mean absolute latencies of SP, AP and standard deviation at 90 dBnHL. The mean absolute latencies of SP and AP were 0.9770 (S.D.=.09814) and 1.8403 (S.D.=.1592) msec respectively.

Table 1. Mean absolute latency of SP, AP and standard deviation when stimulus click rate 7.1/sec at 90 dBnHL.

ECochG Waveform	Latency (msec)	
	Mean	S.D.
SP	0.9770	.09814
AP	1.8403	.1592

3. The amplitude ratio of SP/AP when stimulus click rate 7.1/sec at 90 dBnHL were used.

Table 2 showed the mean SP/AP amplitude ratio and standard deviation at 90 dBnHL. The mean SP/AP amplitude ratio was 0.1733 (S.D.=.07693).

Table 2. Mean and standard deviation of SP/AP amplitude ratio when stimulus click rate 7.1/sec at 90 dBnHL were used.

Amplitude ratio	Mean	S.D.
SP/AP	0.1733	.07693

4. The comparison absolute latencies of AP at 90 dBnHL when different stimulus repetition rates 7.1/sec and 99.9/sec were used.

Table 3 showed that the mean absolute latency of AP were 1.8403 (S.D.=.1592) msec and 2.0437 (S.D.=.1978) msec when 7.1/sec and 99.9/sec click rate stimulus were used respectively. The paired t-test showed significant different between mean absolute latency of AP in different click rate (p-value<0.001).

Table 3. Mean absolute latencies of AP, mean differences, standard deviation and standard deviation differences when different stimulus repetition rates 7.1/sec and 99.9/sec at 90 dBnHL were used.

Rate (click/sec)	n	Absolute latency of AP (msec)				t	P
		Mean	Mean differences	S.D.	S.D. differences		
7.1	60	1.8403		.1592			
			.2034		.0780	20.193***	.000
99.9	60	2.0437		.1978			

Note: *** significant at the p-value < .001

5. The comparison absolute latencies of SP at 90 dBnHL when different stimulus repetition rates 7.1/sec and 99.9/sec were used.

Table 4 showed that the mean absolute latency of SP were 0.9770 (S.D.=.0981) msec and 0.9857 (S.D.=.1021) msec when 7.1/sec and 99.9/sec click rate stimulus were used respectively. The paired t-test showed no significant different between mean absolute latency of SP in different click rate.

Table 4. Mean absolute latencies of SP, mean differences, standard deviation, and standard deviation differences when different stimulus repetition rates 7.1/sec and 99.9/sec at 90 dBnHL were used.

Rate (click/sec)	n	Absolute latency of SP (msec)				t	P
		Mean	Mean differences	S.D.	S.D. differences		
7.1	60	.9770		.0981			
			.0087		.0422	1.592	.117
99.9	60	.9857		.1021			

6. The comparison absolute latencies of AP at 90 dBnHL when different stimulus repetition rate 7.1/sec and 99.9/sec were used in normal hearing male and female adults

Table 5 showed that the absolute latency of AP in males were 1.8633 (S.D.=.1822) msec, 2.0723 (S.D.=.2151) msec, and in females were 1.8173 (S.D.=.1314) msec, 2.0150 (S.D.=.1778) msec when 7.1/sec and 99.9/sec clicks rate stimulus were used respectively. The t-test showed no significant different between absolute latency of AP in males and females both 7.1/sec and 99.9/sec stimulation click rate.

Table 5. Mean absolute latency of AP and standard deviation in normal hearing male and female adults when used different stimulus repetition clicks rate 7.1/sec and 99.9/sec at 90 dBnHL.

Rate (click/sec)	Absolute latency of AP (msec)				t	P
	Males (n=30)		Females (n=30)			
	Mean	S.D.	Mean	S.D.		
7.1	1.8633	.1822	1.8173	.1314	-1.121	.267
99.9	2.0723	.2151	2.0150	.1778	-1.125	.265

7. The comparison absolute latencies of SP at 90 dBnHL when different stimulus repetition rate 7.1/sec and 99.9/sec were used in normal hearing male and female adults

Table 6 showed that the absolute latency of SP in males were 0.9767 (S.D.=.1045) msec, 0.9780 (S.D.=.1069) msec, and in females were 0.9773 (S.D.=.0931) msec, 0.9933 (S.D.=.0984) msec when 7.1/sec and 99.9/sec click rate stimulus were used respectively. The t-test showed no significant different between absolute latency of SP in males and females both 7.1/sec and 99.9/sec at 90 dBnHL.

Table 6. Mean absolute latency of SP and standard deviation in normal hearing male and female adults when used different stimulus repetition clicks rate 7.1/sec and 99.9/sec at 90 dBnHL.

Rate (click/sec)	Absolute latency of SP (msec)				t	P
	Males (n=30)		Females (n=30)			
	Mean	S.D.	Mean	S.D.		
7.1	.9767	.1045	.9773	.0931	.026	.979
99.9	.9780	.1069	.9933	.0984	.578	.565

8. The comparison of clicks ECochG threshold and pure tone average threshold at 500-2000 Hz in normal hearing adults.

Table 7 showed the mean of pure tone average threshold and clicks ECochG threshold were 11.87 (S.D.=3.67)dB and 34.67 (S.D.=6.36)dB respectively. The paired t-test showed significant different between pure tone average threshold and ECochG threshold (p-value<0.001).

Table 7. Mean, mean differences, standard deviation and standard deviation differences of clicks ECochG threshold and pure tone average threshold in normal hearing adults.

Threshold	n	Mean (dB)	Mean differences	S.D.	S.D. differences	t	P
Pure tone	60	11.87		3.67			
			22.80		4.19	35.954***	.000
Click ECochG	60	34.67		6.36			

Note: *** significant at the p-value < .001

9. The amplitude-intensity and latency-intensity function in normal hearing adults.

Table 8 showed Pearson's correlation coefficient between amplitude-intensity and latency-intensity in normal hearing adults. The result showed positive relationship between amplitude and intensity (r=.715,p-value<.001). On the other hand, there was negative relationship between latency and intensity in normal hearing adults (r=-.912,p-value<.001). The amplitude-intensity and latency-intensity function were illustrated in Figure 8.

Table 8. Pearson's correlation coefficient between amplitude-intensity and latency-intensity in normal hearing adults.

	n	Latency		Amplitude	
		r	P	r	P
Intensity	235	-.912***	.000	.715***	.000

Note: *** significant at the p-value < .001

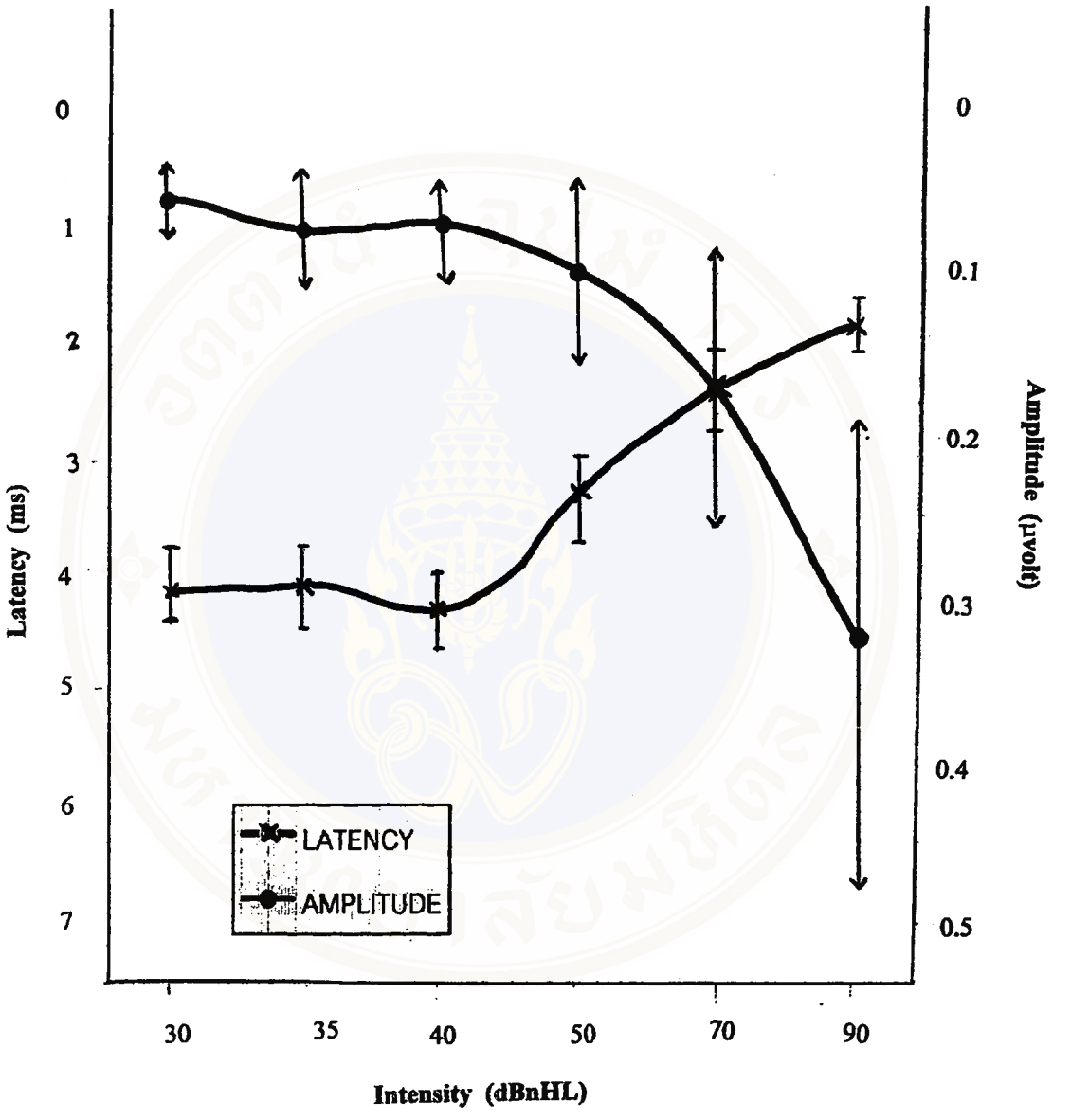

Figure 8 The amplitude-intensity function and latency-intensity function of wave AP

Table 9 showed that the mean absolute latency of AP, and standard deviation when stimulus intensities 90, 70, and 50 dB were used. The mean absolute latency of AP were 1.8403 (S.D.=.1592) msec, 2.4068 (S.D.=.3799) msec, and 3.2773 (S.D.=.4414) msec when 90 dB, 70 dB, and 50 dB stimulus intensities were used respectively. The t-test showed significant different between mean absolute latency of AP in different stimulus intensities (p-value<0.001)

Table 9. Mean absolute latency of AP, and standard deviation when different stimulus intensities 90 dB, 70 dB, and 50 dB were used.

AP latency (msec)	Intensity (dB)					
	90	70	90	50	70	50
Mean	1.8403	2.4068	1.8403	3.2773	2.4068	3.2773
S.D.	.1592	.3799	.1592	.4414	.3799	.4414
t-value	14.059***		28.543***		19.468***	
P-value	.000		.000		.000	

Note: *** significant at the p-value<.001

Table 10 showed that the mean absolute latency of AP, and AP latency shift when stimulus intensities 90, 70, and 50 dB were used. The results showed that when stimulus intensities increased the latency of AP decreased. At high stimulus intensity (70 dB to 90 dB), AP latency slightly decreased were 0.5665 ms (S.D.=0.4118). Low stimulus intensity (50 dB to 70 dB), AP latency markedly decreased were 0.8705 ms(S.D.=0.5823). The latency-intensity function of wave AP were illustrate in Figure 9.

Table 10. Mean absolute latency of AP (±S.D.), and latency shift (±S.D.) when stimulus intensities increased.

Intensity (dB)	N (ears)	AP latency (msec)	Latency shift
		Mean ± S.D.	Mean ± S.D.
90	60	1.8403 ± .1592	-
70	60	2.4068 ± .3799	0.5665 ± .4118
50	60	3.2773 ± .4414	0.8705 ± .5823

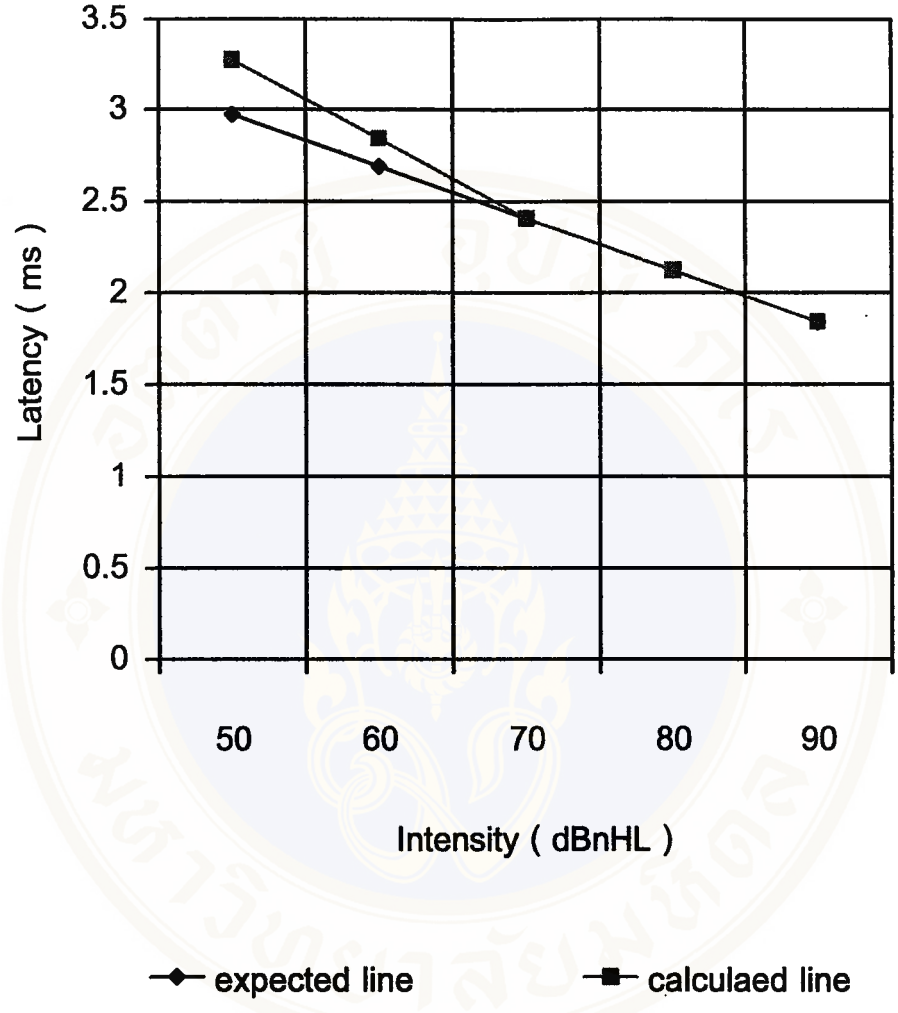

Figure 9 The latency-intensity function of wave AP

CHAPTER V

DISCUSSION

This study was conducted to investigate the normative characteristics of EcochG with extratympanic electrode in sixty normal hearing adult's ears with age ranged from 20 to 40 years. The hypotheses in the study were:

-waveform morphology

-the absolute latencies of wave SP, and AP

-the amplitude ratio of SP/AP

-the click ECochG threshold and pure tone average threshold

-the latency-intensity function and amplitude-intensity function of AP

1. The ECochG waveform morphology when TIPtrode were used in normal hearing adults.

The ECochG waveform morphology were displayed in Figure 7. The results in this study showed SP component of ECochG waveform morphology appeared same direction as AP component 100 %. The stimulus clicks at 90 dBnHL, there were 2 pattern of AP components waveform. The first single peak pattern was found 68.33 %, the later double peak pattern was found 31.67 % when conventional stimulus repetition clicks rate were used. At high stimulus repetition clicks rate, SP could still be robust. In contrast, latency of the AP increased and amplitude decreased. The changing of AP morphology as stimulus repetition rate increased may be due to desynchronization at the cochlear level and perhaps adaptation phenomenon at the synapse between hair cells and auditory nerve afferents (4, 40, 47).

2. The mean amplitude ratio of SP/AP when click stimulus at 90 dBnHL were used.

The mean amplitude ratio of SP/AP when click stimulus at 90 dBnHL used in normal hearing adults were displayed in Table 2. The mean SP/AP amplitude ratio were 0.1733 (S.D.=.07693). The results showed that the SP/AP amplitude ratio were within normal limit when extratympanic electrode were used. This finding agreed with the study of Ferraro (12). He suggested normal SP/AP amplitude ratio in his laboratory (ET ECochG) range from 0.1-0.5 (mean:0.25). In addition, Coat et al. (1984) found normal SP/AP amplitude ratio is only 25 percent (0.25) in normal subjects by ET ECochG. Also, Mori et al (47) studied the role of summating potential in the diagnosis and management of Meniere's disease. The click-induced SP and AP were recorded by extratympanic ECochG. They found when SP/AP ratio exceeded 0.43 the SP was considered to be abnormal.

3. The mean absolute latencies of SP, and AP when different stimulus repetition rates at 90 dBnHL were used in normal hearing adults.

The mean absolute latencies of SP and AP when different stimulus repetition rates at 90 dBnHL used in normal hearing adults were displayed in Table 3, and 4. The results showed that the absolute latency of AP were prolonged as stimulus repetition rate increased from 7.1/sec to 99.9/sec at 90 dBnHL. This results indicated that the latency of AP was significantly different between 7.1/sec and 99.9/sec (p-value<0.001). The results were similar to the finding of Hall (4), Eggermont & Odenthal (40), and Mouney et al. (47). They reported that the latency of AP component increased to over 100 clicks per sec. They suggested that the latency increased may be desynchronization at the cochlear level and perhaps adaptation phenomenon at the synapse between hair cells and auditory nerve afferents. In addition, Ferraro and Ruth (82) found increasing repetition rate beyond 30/sec may cause some adaptation of the AP, and rates on the order of 100/sec would cause maximum depression of AP.

The results indicated that the latency of SP was no significantly different between 7.1/sec and 99.9/sec. This finding was similar to Staller (36). He suggested rate of stimulus presentation also has a significant impact on some components of ECochG. As a neural response, the AP begins to demonstrate amplitude reduction due to adaptation at stimulus rates exceeding approximately 15/sec. The rapid rate fatigues the AP, leaving only an intact SP, which as a hair cell receptor potential does not have a measurable refractory period.

4. The mean absolute latency of SP, and AP when different stimulus repetition rates at 90 dBnHL were used in normal hearing male and female adults.

The mean absolute latency of SP, and AP when different stimulus repetition rates at 90 dBnHL used in normal hearing male and female adults were displayed in Table 5, and 6. The results showed that the absolute latency of SP in male group were 0.9767 msec, 0.9780 msec, AP were 1.8633 msec, 2.0723 msec, and SP in female group were 0.9773 msec, 0.9933 msec, AP were 1.8173 msec, 2.0150 msec when 7.1/sec and 99.9/sec clicks rate stimulus respectively. The results indicated that the latency of SP, and AP were no significantly different between males and females group. This finding was similar to the study of Cox (87) and Jerger and Hall(89). They suggested no gender difference latency and amplitude of AP at low click rate. At high stimulus repetition rate (99.9/sec), there was no research studied difference between males versus females. The results in this study showed no significantly difference SP, AP between males and females group.

5. The mean pure tone average threshold and clicks ECochG threshold in normal hearing adults.

The mean pure tone average threshold and clicks ECochG threshold in normal hearing adults were displayed in Table 7. The results showed that the pure tone average threshold were 11.87 (SD=3.67), the ECochG threshold were 34.67 (SD=6.36). The results indicate that the threshold were significantly different between pure tone average threshold and clicks ECochG threshold ($p<0.001$). The different between ECochG threshold and PTA threshold were 22.80 dB(S.D.=4.19). The results of this study similar to the finding of Eggermont (39), Eggermont Odenthal (40), Yoshie (61), and Parving et al (63). They found threshold for ECochG and behavioral testing were within ± 10 dB in normal hearing subjects, hearing-impaired children, and adults with high-frequency sensorineural loss, when transtympanic recording are made. Accuracy of hearing threshold estimation is poorer with ear canal electrode placement ECochG and/or in person with low-frequency hearing loss. This research studied in normal hearing adults by ear canal electrode (TIPtrode). Extratympanic ECochG threshold were higher than the threshold obtained from Transtympanic ECochG electrode. It was possibly due to the far field recording technique which yielded poorer threshold than the result from the near field recording technique (4, 73).

6. The AP latency-intensity function and amplitude-intensity function in normal hearing adults.

The AP latency-intensity function and amplitude-intensity function in normal hearing adults were displayed in Table 8, and in Figure 9, 10. The results showed positive relationship between amplitude and intensity (r=.715,p-value<.001). On the other hand, there was negative relationship between latency and intensity in normal hearing adults (r=-.912,p-value<.001). The finding of this study agree with the study of Dallos (5), Ruth & Lambert (27), Davis (36), Peake & Kiang (37), Chatrian et al. (38), Eggermont (39), Eggermont & Odenthal (40). Hall (4), and Ruth & Lambert (27). They found AP latency decreased slightly, and amplitude increased markedly as stimulus intensity was increased. One factor in the latency-versus-intensity relationship is the site of cochlear activation. Higher intensity levels activate more basal (high frequency) portions of the cochlea, while lower intensity levels activate more apical portions. The time delay from stimulus onset is shorter for basal versus apical cochlea activation. Another factor is synaptic delay. This delay is less with high than with low stimulus intensity levels (58, 61).

CHAPTER VI

CONCLUSION

The effects of stimulus clicks on the extratympanic ECochG was investigated in this study. Sixty normal hearing adult's ears with ages ranged from 20 to 40 years were used as subjects. The clicks stimuli with 90 dBnHL were used. Stimuli were presented at the rates of 7.1 and 99.9/sec. The polarity of the clicks was alternate and the filter setting was from 10 to 1500 Hz. The findings of this study suggested the following conclusions:

1. The ECochG waveform morphology showed SP component, and AP component (as showed in Figure 7 (Page 34)). The SP appeared to be the same direction as AP 100%. The single peak AP were 68.33 %, and the separate peak AP were 31.67 %.

2. The mean amplitude ratio of SP/AP when click stimulus at 90 dBnHL used in normal hearing adults were 0.1733 (S.D.=.07693).

3 . The absolute latency of AP was significantly increased as stimulus repetition rate increased from 7.1/sec to 99.9/sec ($P < 0.001$). The absolute latency of SP showed no significant difference when stimulus repetition rate increased.

4. The absolute latency of SP, and AP showed no significant difference between male and female group when 7.1/sec and 99.9/sec click rate stimulus were used.

5. The mean pure tone average threshold were 11.87 dB (S.D.=3.67), and the ECochG threshold were 34.67 dB (S.D.=6.36). The results indicate that the ECochG threshold were significantly higher than those of pure tone average threshold ($P < 0.001$).

6. The signal intensity had significant effects on AP latency and amplitude. When intensity increased the amplitude increased(r=.715, p-value<.001). On the other hand, when intensity increased the latency decreased(r=-.912, p-value <.001). At high stimulus intensity (70dB to 90dB), the decrement of AP latency was 0.5665 ms (S.D.=0.4118). At low stimulus intensity (50dB to 70dB), the decrement of AP latency was 0.8705 ms (S.D.=0.5823).

Recommendations

From the results of this study, some recommendation and future research study have been proposed.

1. ECochG test should be investigated in patients with various degrees of sensorineural hearing loss.

2. ECochG test should be investigated in patients with Meniere's disease.

3. ECochG test should be investigated in patients with other SNHL (not Meniere's disease).

4. ECochG test should be investigated in subjects with different age groups.

5. The stimulus tone burst (frequency specific) should be used as additional stimulation during ECochG test.

6. ECochG test should be compared between extratympanic electrode and transtympanic electrode.

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APPENDIX

RAW DATA

Table A-1 Raw data of absolute latencies of wave SP and AP at 7.1/ses and99.9/sec with intensity constant at 90 dBnHL.

Subjects	Sex	Age	Rate (click/s)	Absolute latencies (msec)	
				SP	AP
1	F	33	7.1	1.00	1.80
			99.9	1.02	1.95
2	F	33	7.1	0.88	1.70
			99.9	0.90	1.80
3	F	30	7.1	0.93	2.00
			99.9	0.88	2.20
4	F	30	7.1	0.93	1.95
			99.9	0.95	2.20
5	M	36	7.1	1.17	2.05
			99.9	1.15	2.38
6	M	36	7.1	1.10	2.08
			99.9	1.15	2.38
7	F	29	7.1	1.05	1.98
			99.9	1.05	2.20
8	F	29	7.1	1.02	2.00
			99.9	1.05	2.20
9	F	33	7.1	0.93	1.75
			99.9	0.95	1.88
10	F	33	7.1	0.98	1.63
			99.9	1.05	1.75
11	F	24	7.1	0.98	2.05
			99.9	1.05	2.20
12	F	24	7.1	0.95	1.70
			99.9	0.98	1.80
13	F	38	7.1	0.98	1.95
			99.9	1.00	2.08

Table A-1 Raw data of absolute latencies of wave SP and AP at 7.1/ses and99.9/sec with intensity constant at 90 dBnHL (continued).

Subjects	Sex	Age	Rate (click/s)	Absolute latencies (msec) SP	AP
14	F	38	7.1	1.05	1.95
			99.9	1.13	2.30
15	M	31	7.1	0.88	1.73
			99.9	0.90	1.88
16	M	31	7.1	0.93	1.65
			99.9	0.90	1.77
17	M	38	7.1	0.88	1.63
			99.9	0.80	1.80
18	M	38	7.1	0.80	1.67
			99.9	0.90	1.80
19	M	33	7.1	1.13	1.88
			99.9	1.20	1.95
20	M	33	7.1	0.90	1.88
			99.9	0.88	2.13
21	F	22	7.1	0.93	1.63
			99.9	0.95	1.77
22	F	22	7.1	0.93	1.70
			99.9	0.88	1.80
23	F	40	7.1	1.02	1.92
			99.9	1.05	2.35
24	F	40	7.1	1.05	1.90
			99.9	1.08	2.33
25	M	23	7.1	1.02	2.05
			99.9	1.05	2.25
26	M	23	7.1	1.13	2.05
			99.9	1.15	2.30

Table A-1 Raw data of absolute latencies of wave SP and AP at 7.1/ses and99.9/sec with intensity constant at 90 dBnHL (continued).

Subjects	Sex	Age	Rate (click/s)	Absolute latencies (msec) SP	AP
27	F	34	7.1	1.13	1.95
			99.9	1.15	2.05
28	F	34	7.1	1.17	1.95
			99.9	1.20	2.15
29	F	24	7.1	1.05	1.85
			99.9	1.05	2.05
30	F	24	7.1	1.05	1.77
			99.9	1.05	1.95
31	M	30	7.1	0.88	1.63
			99.9	0.82	1.85
32	M	30	7.1	0.90	1.65
			99.9	0.95	1.83
33	F	39	7.1	0.80	1.75
			99.9	0.88	1.92
34	F	39	7.1	0.80	1.73
			99.9	0.85	1.92
35	M	36	7.1	0.95	2.00
			99.9	0.98	2.20
36	M	36	7.1	0.93	2.03
			99.9	1.00	2.30
37	M	32	7.1	0.82	1.73
			99.9	0.85	1.90
38	M	32	7.1	0.95	1.63
			99.9	0.98	1.92
39	M	31	7.1	1.00	1.98
			99.9	0.98	2.20

Table A-1 Raw data of absolute latencies of wave SP and AP at 7.1/ses and99.9/sec with intensity constant at 90 dBnHL (continued).

Subjects	Sex	Age	Rate (click/s)	Absolute latencies (msec) SP	AP
40	M	31	7.1	0.95	1.92
			99.9	0.95	2.15
41	M	35	7.1	1.13	2.13
			99.9	1.05	2.30
42	M	35	7.1	1.08	2.08
			99.9	1.00	2.42
43	F	27	7.1	1.05	1.88
			99.9	1.13	2.15
44	F	27	7.1	1.10	1.88
			99.9	1.05	2.05
45	M	28	7.1	0.95	1.95
			99.9	0.95	2.17
46	M	28	7.1	0.95	2.03
			99.9	0.95	2.20
47	F	27	7.1	0.88	1.70
			99.9	0.95	1.90
48	F	27	7.1	0.82	1.75
			99.9	0.82	1.88
49	M	37	7.1	1.00	1.65
			99.9	0.95	1.80
50	M	37	7.1	1.05	1.70
			99.9	1.05	1.90
51	M	22	7.1	1.00	1.83
			99.9	1.02	1.92
52	M	22	7.1	1.00	1.77
			99.9	1.03	1.92

Table A-1 Raw data of absolute latencies of wave SP and AP at 7.1/ses and99.9/sec with intensity constant at 90 dBnHL (continued).

Subjects	Sex	Age	Rate	Absolute latencies (msec)	
			(click/s)	SP	AP
53	F	27	7.1	1.05	1.73
			99.9	1.00	1.95
54	F	20	7.1	0.98	1.67
			99.9	0.96	1.95
55	M	27	7.1	1.17	2.17
			99.9	1.15	2.40
56	M	30	7.1	0.95	2.00
			99.9	0.95	2.25
57	M	28	7.1	0.85	1.65
			99.9	0.85	2.00
58	M	28	7.1	0.85	1.70
			99.9	0.88	1.90
59	F	20	7.1	0.85	1.60
			99.9	0.82	1.80
60	F	20	7.1	0.98	1.70
			99.9	0.92	1.92

F=Female

M=Male

Table A-2 Raw data of SP/AP amplitude ratio with intensity constant at 90 dBnHL.

Subjects	Sex	Age	Amplitude Ratio
			SP/AP
1	F	33	0.08
2	F	33	0.14
3	F	30	0.15
4	F	30	0.10
5	M	36	0.12
6	M	36	0.18
7	F	29	0.17
8	F	29	0.18
9	F	33	0.07
10	F	33	0.08
11	F	24	0.21
12	F	24	0.23
13	F	38	0.15
14	F	38	0.38
15	M	31	0.06
16	M	31	0.21
17	M	38	0.17
18	M	38	0.10
19	M	33	0.26
20	M	33	0.25
21	F	22	0.11
22	F	22	0.11
23	F	40	0.20
24	F	40	0.19
25	M	23	0.26
26	M	23	0.31
27	F	34	0.16
28	F	34	0.18
29	F	24	0.31
30	F	24	0.21

Table A-2 Raw data of SP/AP amplitude ratio with intensity constant at 90 dBnHL(continued).

Subjects	Sex	Age	Amplitude Ratio
			SP/AP
31	M	30	0.17
32	M	30	0.13
33	F	39	0.03
34	F	39	0.18
35	M	36	0.17
36	M	36	0.09
37	M	32	0.11
38	M	32	0.17
39	M	31	0.18
40	M	31	0.09
41	M	35	0.22
42	M	35	0.30
43	F	27	0.15
44	F	27	0.32
45	M	28	0.24
46	M	28	0.12
47	F	27	0.25
48	F	27	0.08
49	M	37	0.27
50	M	37	0.13
51	M	22	0.27
52	M	22	0.27
53	F	27	0.07
54	F	20	0.21
55	M	27	0.15
56	M	30	0.08
57	M	28	0.05
58	M	28	0.24
59	F	20	0.14
60	F	20	0.19

F=Female, M=Male

Table A-3 Raw data of pure tone average threshold and click ECochG threshold.

Subjects	Sex	Age	Threshold (dBnHL)	
			Pure tone average	ECochG
1	F	33	10	30
2	F	33	10	30
3	F	30	7	30
4	F	30	8	30
5	M	36	15	40
6	M	36	17	50
7	F	29	10	30
8	F	29	10	30
9	F	33	12	30
10	F	33	13	35
11	F	24	17	30
12	F	24	12	30
13	F	38	12	30
14	F	38	17	40
15	M	31	13	35
16	M	31	12	30
17	M	38	17	30
18	M	38	15	30
19	M	33	15	40
20	M	33	20	50
21	F	22	10	30
22	F	22	12	30
23	F	40	15	30
24	F	40	17	40
25	M	23	15	35
26	M	23	17	35
27	F	34	12	40
28	F	34	13	40
29	F	24	8	30
30	F	24	8	30

Table A-3 Raw data of pure tone average threshold and click ECochG threshold (continued).

Subjects	Sex	Age	Threshold (dBnHL)	
			Pure tone average	ECochG
31	M	30	8	30
32	M	30	8	30
33	F	39	13	40
34	F	39	12	35
35	M	36	13	40
36	M	36	15	50
37	M	32	5	30
38	M	32	5	30
39	M	31	7	30
40	M	31	10	30
41	M	35	15	50
42	M	35	17	50
43	F	27	8	40
44	F	27	7	30
45	M	28	5	30
46	M	28	8	30
47	F	27	10	30
48	F	27	17	40
49	M	37	15	30
50	M	37	15	40
51	M	22	15	40
52	M	22	10	30
53	F	27	12	40
54	F	20	7	30
55	M	27	10	35
56	M	30	15	40
57	M	28	8	30
58	M	28	8	30
59	F	20	13	40
60	F	20	12	30

F=Female, M=Male

Table A-4 Raw data of absolute latency of AP when stimulus intensities 90dBnHL, 70dBnHL, and50 dBnHL were used.

Subjects	Sex	Age	Absolute latency of AP (msec)		
			90dBnHL	70dBnHL	50dBnHL
1	F	33	1.80	2.08	3.15
2	F	33	1.70	2.22	3.08
3	F	30	2.00	2.30	3.20
4	F	30	1.95	2.33	3.00
5	M	36	2.05	3.38	3.85
6	M	36	2.08	3.53	4.22
7	F	29	1.98	2.67	3.05
8	F	29	2.00	2.60	3.05
9	F	33	1.75	2.20	3.33
10	F	33	1.63	2.03	2.92
11	F	24	2.05	2.25	3.00
12	F	24	1.70	2.95	3.80
13	F	38	1.95	2.17	2.65
14	F	38	1.95	2.42	2.63
15	M	31	1.73	2.90	3.22
16	M	31	1.65	1.85	3.00
17	M	38	1.63	2.05	3.33
18	M	38	1.67	2.13	3.22
19	M	33	1.88	2.15	3.20
20	M	33	1.88	2.35	4.03
21	F	22	1.63	1.95	2.90
22	F	22	1.70	2.13	2.90
23	F	40	1.92	2.70	3.17
24	F	40	1.90	2.88	3.78
25	M	23	2.05	2.72	3.58
26	M	23	2.05	2.72	4.05
27	F	34	1.95	3.15	3.63
28	F	34	1.95	2.42	3.22
29	F	24	1.85	2.45	3.42
30	F	24	1.77	2.38	3.17

Table A-4 Raw data of absolute latency of AP when stimulus intensities 90dBnHL, 70dBnHL, and50 dBnHL were used (continued).

Subjects	Sex	Age	Absolute latency of AP (msec)		
			90dBnHL	70dnHL	50dBnHL
31	M	30	1.63	1.953	3.38
32	M	30	1.65	1.85	3.10
33	F	39	1.75	2.63	3.53
34	F	39	1.73	2.38	3.28
35	M	36	2.00	2.38	3.40
36	M	36	2.03	2.45	3.88
37	M	32	1.73	2.20	2.97
38	M	32	1.63	1.95	2.38
39	M	31	1.98	2.42	3.03
40	M	31	1.92	2.40	3.20
41	M	35	2.13	2.63	4.30
42	M	35	2.08	2.97	4.18
43	F	27	1.88	3.22	4.05
44	F	27	1.88	2.33	3.30
45	M	28	1.95	2.95	3.70
46	M	28	2.03	2.65	3.55
47	F	27	1.70	2.05	3.38
48	F	27	1.75	2.08	3.25
49	M	37	1.65	2.03	2.30
50	M	37	1.70	2.20	2.65
51	M	22	1.83	2.45	3.50
52	M	22	1.77	2.30	2.97
53	F	27	1.73	2.10	2.65
54	F	20	1.67	2.08	3.45
55	M	27	2.17	2.40	3.15
56	M	30	2.00	2.30	3.30
57	M	28	1.65	1.95	3.40
58	M	28	1.70	2.28	2.95
59	F	20	1.60	2.05	2.63
60	F	20	1.70	2.72	3.08

F=Female, M=Male

BIOGRAPHY

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