VARIATIONS IN BIOVOLTAGE PARAMETERS AGAINST AN EXPERT SYSTEM OF ACUPUNCTURE THERAPY FOR PATIENTS WITH TINNITUS

Yudha Herlambang¹, Suhariningsih², Totok Soehartanto³
Trunojoyo University, Madura¹
Faculty of Science and Technology, Airlangga University²
Department of Physical Engineering, FTI-ITS³
ngumarsb@yahoo.com

ABSTRACT

Acupuncture is publicly well known as an alternative treatment for several diseases. The problem that arises is the absence of measurable physical parameters to determine the effects of acupuncture on a therapy. These measurable physical parameters will be useful both for the study of the precision of acupuncture points and determination of the extent of the effects of acupuncture. Physical parameters in the present study were based on the electrical activity of the body’s tissues subjected to acupuncture since acupuncture is aimed at stimulating the subcutaneous neural and muscular tissues. The activated neural and muscular tissues would generate electrical impulses called biovoltage. This work was part of a main research on an expert system that used acupuncture therapy for patients with tinnitus (ringing in the ears). The purpose of the study was to determine the most significant physical parameters of the time domain (amplitude) and frequency domain of acupuncture by using needles as electrodes for reading subcutaneous biovoltage at the needle insertion points (acupoints). The bioamplifier ADS1198 from Texas Instruments was used to read biovoltage. Subjects were 10 individuals with tinnitus due to nerve deafness or sensorineural hearing loss (SNHL). Needle insertion was performed 6 times on different days, followed up by hearing observation on the second, fourth, and sixth (last) occasion of acupuncture therapy and pre-acupuncture therapy in order to determine the progression of the individuals’ levels of hearing. Measurements by the use of bioamplifier interfaced with a PC (personal computer) showed that the biovoltage parameter for time domain (amplitude) was ± 30 mVolt, which was more significant after being fed to the system expert. The biovoltage parameter for frequency domain did not show a trend in accordance with the testing sequence of subjects.

Keywords: Biovoltage, acupoints, tinnitus, deafness, Sensorineural hearing loss (SNHL), Hearing observation, bioamplifier, acupuncture

INTRODUCTION

Bioelectric phenomenon

Biophysical studies generated quite noticeable data on the electrical properties of acupuncture points relative to those of control [1]. Due to their electrical properties, acupuncture points are those areas that generate electrical properties and, as electrodes, they are equivalent to those cells physiologically referred to as electrically active cells.

Hence, acupuncture points are capable of generating electronic flows in the cells with equivalent polarization potentials. Acupuncture points are located subcutaneously and on the muscular fascia.

It is widely known that acupuncture points have bioelectric signals that indicate whether an individual is healthy or diseased since an acupuncture point represents a “reflection” or “window” of a particular organ [1]. With the disruption of an organ, the biovoltage magnitude of an acupuncture point of the diseased organ will be different from the profile of biopotential magnitude of healthy organs. According to the
concept of Yin-Yang balance, a healthy organ has a smooth flow of the Chi energy, a small flow resistance, and a smooth conductivity; in other words, it can be said that its biopotential difference gets smaller. On the contrary, a diseased organ has less smooth flow of Chi energy, large flow resistance, and small flow conductivity; there is a large measured potential difference. Based on the above rationale, there should be a trend or fluctuation in the magnitude of bioelectric signal that can be used as an indicator of the degree of cure of certain diseases by using acupuncture therapy.

THEORETICAL FRAMEWORK

Acupuncture Points General Description

According to Leong, the term acupuncture derives from the Latin acus that means ‘needle’ and punctura that means ‘to prick’ [2]. Acupuncture is a treatment by insertion of needles at specific points on the surface of the body to relieve pain and treat certain health conditions.

Acupuncture means the act of pricking sharp needles of varying length on one or a few or even tens of points located in the body, including the head, with varying degrees of pricking depth and manipulation. By inserting needles at one or several points and leave them for a while, it is expected that the Yin-Yang balance will be reached so as to eliminate the disharmonious states.

An acupuncture point is a collection of cells with distinct activities relative to those cells outside the acupuncture points and electrically has the characteristics of “high voltage, low resistance” in which technetium pertechnetate isotopes migrate actively [1,3].

Thus, there are two fundamental approaches: molecular biology of functional processes in the cell morphology and biophysics of the process of energy flow.

Acupuncture Points Relevant to Inner Ear Disorder (Tinnitus)

a. The Wai Guan Point (SJ.06)

The location this acupoint described in figure 1. below

![The Wai Guan acupuncture point (SJ.6) for the therapy of tinnitus](image)

b. The Ting Gong Point (Thing Kung, SJ.19)

It is located at mid-tragus or the middle portion of the ear’s tragus. It is exactly in the groove between the ridges of the ear’s lobe (tragus) and the jaw joint when the mouth is slightly opened.

![The Ting Gong acupuncture point (SJ.19) (source: Leong, 2008)](image)

c. The Yi Feng Point (SI.17)

It is located post-annularly, i.e., on the midline of the ear lobe and the mastoid.
Bioelectricity

Bioelectricity is the energy present in the living body that derives from ATP (adenosine triphosphate). ATP is produced by one part of the cell called the mitochondria in the process of respiration. In other words, bioelectricity is all related to electricity produced by a living body. Electricity in question is everything related to the charged ions present in the body and the electric fields generated by those ions and the resulting potential.

![Image of the wave of electrical activity of nerve cells](http://alifis.wordpress.com/category/fisika-corner/fisika-kesehatan/)

**Tinnitus phenomenon as a hearing impairment**

**Definition**

Tinnitus is the perception of sound in the ears or in the head. Various definitions of tinnitus have been made [4]. According to Jastreboff,(1999), tinnitus is a ringing, roaring, whistling sound or other sounds in the ears that are purely subjective [5]. According to Anthonely (2000), tinnitus is an otological symptom, has many properties, and can arise as a result of many causes [6]. It is a subjective phenomenon commonly found in many diseases.

**Classification**

In general, tinnitus is divided into two types:
1. Objective tinnitus, also called dynamic tinnitus, vibratory tinnitus, and pseudo- or extrinsic tinnitus. Objective tinnitus can also be heard by the examiner or other person [7].
2. Subjective tinnitus, also called static tinnitus, non-vibratory tinnitus, “true” tinnitus or intrinsic tinnitus. This type of tinnitus can only be heard by the sufferer [7,8].

**Expert System**

An expert system is a computer application program that has the ability as that possessed by an expert in a particular field to solve various issues related to the field. An expert system is a computer-based system that uses knowledge, facts, and reasoning techniques in solving problems that usually can be solved by an expert in the relevant field [9].

The name ‘expert’ is derived from the term ‘knowledge-based expert system’. An expert system is a one that uses human knowledge stored in the computer to solve problems that generally require the expertise of a person. In other words, an expert system is an interactive computer-based decision-making system that uses facts and heuristics to solve a variety of
Conceptual Framework of the Study

Acupuncture point is a therapeutic point in acupuncture. This point is a “reflection” or “window” of an impaired organ since at this point there are bioelectric signals that are characteristic of that point. Acupuncture points have the properties and characteristics of high electrical conductivity or low electrical resistance; thus, it has a larger electrical conductivity than the surrounding areas. Electrical conductivity triggers cell activities of the acupuncture points in accordance with the information contents brought by the impaired organ. Acupuncture, closely associated with the concept of Yin-Yang balance, is aimed at balancing “the flow of Chi energy”. In the patients’ diseased organs, the Chi energy in the meridians does not flow smoothly. With acupuncture therapy, the Yin-Yang balance is expected to occur, hereby smoothing the Chi energy.

In other words, it reduces biopotential difference or imbalanced flow of Chi energy on the meridian of the organ points in question. The tendency of fluctuations in bioelectric signals on the acupuncture points have the potential to be used as an indicator of the rate of healing. In the future, this phenomenon can potentially be used as an indicator or monitor of patients’ healing rate during the acupuncture therapy.

By recording the trends or fluctuations in the magnitude of bioelectric signals on the acupuncture points during the therapy, combined with the results of medical tests diagnosed by physicians or competent experts during the acupuncture therapy, an idea can be created in the form of tabulated database stored in the computer memory as a “knowledge base”. It is useful for an expertise-based intelligent system for monitoring the rate of healing of patients with “certain” disease by producing an output of the level of the patients’ health improvement in the form of acceptable medical variables. Individuals with tinnitus or ringing in the ears are subjected to hearing tests, among others, by using the THI (Tinnitus Handicap Inventory) test scoring.

The proposed hypothesis in the present study is as follows: “How can the trends in biopotential or bioelectric signals that are measured in a time-function manner from the selected acupuncture points (Wai Guan, Ting Gong, and Yi Feng) be represented with the help of medical hearing tests to indicate the rate of healing of patients with Vertigo and Tinnitus who have undergone one acupuncture session (6 times)?

MATERIALS AND METHODS

The Wai Guan acupuncture points (SJ-5) of the left and right arms were selected since they are on the Shao Yang meridian of the arms (the San Jiao or SJ) that constitutes the Triple Heater meridian, which topographically passes the arms in the figure below, drawn in blue. This meridian pathway continues to the head through the Yi-Feng acupuncture point (SJ-17), also depicted as the blue line, as is the Wai Guan acupuncture points mentioned above. Thus, the Yi Feng points as the points close to the ears can directly stimulate the main organs targeted for the therapy, i.e., the ears. The figure below shows the San Jiao (SJ) meridian that passes through the Wai Guan and Yi Feng acupuncture points (the blue line).

Fig. 5 – The pathway of the San Jiao (SJ) Meridian that passes through the Wai Guan (SJ-5) points of the arms (the blue line is the SJ meridian; the acupuncture point is on the dot 5).
Fig. 6 – The continuation of the San Jiao (SJ) Meridian pathway that passes through the Yi Feng acupuncture point (SJ-17) in the head (the blue line is the SJ meridian; the acupuncture point is on the dot 17).

Since the Ting Gong acupuncture points (SI-19) of left and right ears are those points close to the ears (auricular) and located in the small intestine (SI) meridian (red in the figure), those points can directly stimulate the ears, which are the targeted abnormal organs to be subjected to the therapy. The location of meridian Small Intestine (SI-19) which contains SI-19 acupoints, namely Ting Gong, showed below:

Fig. 7 – The pathway of Small Intestine (SI) Meridian which passes through the Ting Gong acupuncture point (SI-19) in the head (the red line is the SI meridian; the position is on the dot 19, DU19).

Then, Bioelectricity is measured by using the Data Acquisition Hardware ADS1198 FE manufactured by Texas Instruments [10] (www.ti.com), as shown below:

Fig. 8 – Acquisition Data Hardware ADS1198 FE Texas Instruments and Display Monitor.

The data acquisition device has been modified, as shown above, by adding a USB cable to a laptop as a means to display the resulting graphs and figures from the biovoltage measurement of the above acupuncture points. In addition, the device has been modified by adding 8 cables connected to the alligator clip electrodes. These electrodes served to “catch” the bioelectric signals from the acupuncture needle tips.

However, there would be only 6 electrodes used, in accordance with the number of tinnitus acupuncture points to be used (the Wai Guan points of the left and right arms, the Yi Feng points of the left and right ears, and the Ting Gong points of the left and right ears). Patients were subjected to needle insertion for 15 minutes. In first 5 minutes, the patients were left to relax in order to achieve the balance of the body’s metabolism. In the next 10 minutes, biovoltage was measured at the 6 acupuncture points mentioned above. Measurements were performed simultaneously after attaching electrodes to the needles. Needles were inserted perpendicular to the skin surface, as depicted below:

Fig. 9 – Insertion of acupuncture needles.
Subsequently, during bioelectric measurements, the sampling time parameter was set, in which 500 data samples would be taken in order to obtain as many as possible information on the magnitude of the recorded analog voltage bio-signals. This was performed with the consideration that the more analog signals sampled, the more information from the measurement results would be recorded or obtained. Since the measuring instrument used in the study had a 125 SPS (sampling per second) capacity to record data, then one biovoltage recording took approximately 4 seconds (500/125). Each data recording generated 500 lines of biovoltage data for the 6 acupuncture points studied. For the purpose of data precision, 25 to 30 data were recorded for every single acupuncture therapy for each patient. This study used a sample of 9-10 individuals with tinnitus aged 20 to 60 yrs taken randomly, irrespective of their gender. The type of tinnitus (ringing in the ears) used as the inclusive criterion in this study was the tinnitus caused by neural deafness or SNHL (sensorineural hearing loss). This type of tinnitus is associated with inner ear disorders, including the auditory nerves leading to the temporal lobe of the brain that process auditory information. The auditory nerves are called the acoustic nerves (n.VIII). This type of SNHL disorders is due to many factors including the use of drugs with improper dose, noise exposure/acoustic trauma, trauma capitis or impacts. The types of tinnitus caused by conduction hearing loss (CHL) or mixed hearing loss, such as those caused by a ruptured eardrum, were excluded since they could not possibly be cured by acupuncture therapy. Sample (n) was calculated by using the following formula:

\[ n = \frac{(\sigma^2)(\frac{Z_{\alpha/2}}{Z_{\alpha/2}})^2}{(\mu_2 - \mu_1)^2} \]  

hence:

\[ n = \text{amount of sick human for sample} \]

\[ \sigma = \text{standard deviation} \]

\[ \mu_2 = \text{mean after acupuncture treatment} \]

\[ Z = \text{the value of distribution normal table (by using alpha=0.05)} \]

Operationally, the sample of selected patients or patients fulfilling the inclusion criteria was subjected to an initial hearing test and medical anamnesis for the history of tinnitus. Patients who did not meet the inclusion criteria were excluded from the sample. Patients must also provide informed consent in order to meet the requirements of the Medical Code of Ethics. It was followed up by acupuncture therapy for 6 times (or half session). After every 2 times of acupuncture therapy, hearing examination (ENT) was performed again in order to determine the effects or developments up to the last hearing test or after the last (the sixth) acupuncture therapy. During every acupuncture therapy, biovoltage was measured at the therapy points as described above. For the purpose of hearing tests, the subjective questionnaire of THI (Tinnitus Handicap Inventory) was used. Additionally, the following more objective tests of hearing levels were used consecutively: Audiometric Test (a yet subjective hearing test), Tympanogram (test of tympanic membrane or eardrum and ear reflexes), OAE (Otoacoustic Emission), BERA (Brain Auditory Evoked Response), and ASSR or Physiological audiogram. It is known that the BERA is an adequately reliable hearing test since it measures the brain’s responses to impulse of sound pressure levels inputted to the hearing organs. The ASSR is almost the same as the audiometric test, but it measures the brain’s responses to impulse of frequencies and sound pressure levels inputted to human auditory organs.

In this study, an Expert System was designed to monitor the rate of hearing improvement of tinnitus patients as the results of acupuncture therapy by using IF THEN production rules based on the Forward Chaining Rules. In doing so, rules were arranged to form Knowledge Database. These rules would include an input of parameters involved in the 6 types of hearing tests mentioned earlier (e.g. Sound Pressure Level and frequency (Horizontal)), as well as
the Measured Biovoltage Values during the acupuncture therapy at the acupoints where the needles were inserted. The output or the “Answer” from the Expert System is the results of diagnosis in the form of Hearing Improvement Levels (Normal, Mild, Moderate, Severe Hearing Loss). The “Answer or Diagnosis” of the Expert System version would be compared with Doctor’s Diagnosis or verification as the validation tests. In case of a difference found, a constant would be determined. Thus, the Expert System was expected to serve as an Monitoring Device of the Hearing Levels of People with Tinnitus or ringing in the ears by using acupuncture therapy for 6 times. The Expert System was designed to facilitate and assist the doctor or help people with tinnitus to determine their hearing levels in case of unavailability of doctor when needed.

RESULTS AND DISCUSSION

Biovoltage Signalling

The results of acupuncture measurement in the time domain showed biovoltage values (volts) that had similarities and relationships between different treatment times. Trend, which is certainly associated with better therapeutic results, is shown in Figure 11.

![Fig. 11- A declining trend in biovoltage signals (volts).](image)

In addition to the declining trend in signals usable for an expert system, the Root Mean Square (RMS) values could also be used since they had regularity and also a declining trend as with the biovoltage signals. The RMS value can be seen in Figure 12.

![Fig. 12 - Inter-therapy RMS](image)

In detail, the decrease in the RMS signals, sampled at the red circled points, can be seen in Figure 13 below:
biovoltage measurement, and there was one output, the diagnosis, which was also equipped with an additional menu to accommodate Patients’ Complaints, anamnesis data, as well as Patients’ History.

The rules that apply to the Interpretation of Hearing Test Results according to the types that would “be taught” to the Intelligent System, are presented below:

**OAE (Otoacoustic Emission):** Patient is categorized as Refer or Fail (abnormal) if the dB-NF value is below 7 and categorized as Pass or normal if the value of dB-NF is above 7.

**Tympanogram:** Test Results is in the form of a graph, with the following interpretation rules:
- **Type A** or Normal Hearing: if the examination results show that the peak amplitude curve is in between points 1 and 2, which is considered normal.
- **Type B** or Neural Attachment or Attached Tubes: if the examination results show a curve with no or flat peak.
- **Type A with High Peak:** if the examination results show that the peak amplitude curve is in between points 2 and 3, which is categorized as Normal with High Peak.
- **Type A with Very High Peak:** if the examination results show that the peak amplitude curve is in between point 3 and nearly point 4, which is categorized as a Ossicle Dislocation.
- **Type AD:** if the examination results show a flat curve slope on the right and the left of the Y axis, the peak of the curve is between points 0.1 and 0.5, which is categorized as Osteosclerosis or ossicle stiffness.
- **Type C:** if the examination results show that the curve peak shifts to the left of the Y axis to approximately −300 dB, which is categorized as Tube Occlusion.

**BERA (Brain Auditory Evoked Response) or Evoked Potential Response**

- For impulse sound pressure of **20dB**, if the time latency in the V wave is < 8 ms then it is categorized as Normal hearing; if the...
time latency is above that value, then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 30dB, if the time latency in the V wave is < 7.5 ms then it is categorized as Normal hearing; if the time latency is above that value, then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 40dB, if the time latency in the V wave is < 7 ms then it is categorized as Normal hearing; if the time latency is above that value then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 50dB, if the time latency in the V wave is < 6.5 ms then it is categorized as Normal hearing; if the time latency is above that value then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 60dB, if the time latency in the V wave is < 6.3 ms then it is categorized as Normal hearing; if the time latency is above that value then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 70dB, if the time latency in the V wave is < 6 ms then it is categorized as Normal hearing; if the time latency is above that value then it is categorized as SNHL (Neural Deafness).

- For impulse sound pressure of 80dB, if the time latency in the V wave is < 5.8 ms then it is categorized as Normal hearing; if the time latency is above that value then it is categorized as SNHL (Neural Deafness).

The V wave is the peak wave that serves as the main indicator of the BERA examinations, which is in the time latency response of 5 to 7.5 ms. Time latency is a response time generated by the auditory organ, i.e., the colliculus located within the organ of Corti of the inner ear, when given a stimulus such as sound at a certain pressure level gradually (20 to 80 dB). In BERA examination, the case of the highest sound pressure levels (70 dB and 80 dB) but with slow response, leading to a high time latency and thus delayed response of the colliculus inferior (the part of Organ Corti at inner ear) to low until high sound levels, represents one indication of a disorder or abnormality in hearing levels. Then, the examination proceeds with the most objective type of Hearing test, i.e., the ASSR or Physiological Audiogram.

**Tinnitus Handicap Inventory Questionnaire (THI Questionnaire)**

The Rule applied in this part is almost the same with Audiometry is listed below:

Total THI Score: (number of ‘Yes’ responses x 4) + (number of ‘Sometimes’ responses x 2)

Then Determine presence or categorical of perceived tinnitus handicap based on total THI score had been calculated above:

- 0-16: Slight or No Handicap (Grade 1)
- 18-36: Mild Handicap (Grade 2)
- 38-56: Moderate Handicap (Grade 3)
- 58-76: Severe Handicap (Grade 4)
- 78-100: Catastrophic Handicap (Grade 5)

**Audiometric Test & ASSR**

The ASSR and Audiometric Test and THI Questionnaire have a similarity in test results with regard to the frequency (Hz) of sound pressure function or SPL (dB). The rules of reading are the same, as follows:

- Normal category, if the dB value is −10 to −15
- Slight or Mild Deafness, if the dB is 16 to 25
- Moderately Mild Deafness, if the dB is 26 to 40
- Moderate Deafness, if the dB is 41 to 55
- Moderately Severe Deafness, if the dB is 56 to 70
- Severe Deafness, if the dB is 71 to 90
- Profound Deafness, if the dB is above 90

In this case, the System will ask the user to input the values of frequency and sound pressure level in dB for each frequency, so the system will automatically calculate the average decibel for each left and right ear. Subsequently, on the basis of the average dB value, the System will make categorization based on the above intervals.

It means the “answer” or diagnosis of the Expert System in the form of Hearing Levels that will be compared with the ENT doctor’s diagnosis. Furthermore, the Expert System was designed to
provide recommendations to the user/patient, such as “use hearing aids”, etc.

CONCLUSION

1. Based on the results of biovoltage measurement, there is a tendency of periodic biovoltage graphics trend form, which was due to the repeated nature of body’s metabolism. The decreasing trends occurring with the sequence of therapy is related to the therapeutic effect of acupuncture.

2. Graphics was measured at acupuncture points in the microvolt to millivolt order.

3. Some of the subjects in the study were used regardless of their ages due to the difficulty in obtaining individuals with tinnitus. The subjects to be subjected to ENT examination should be those with tinnitus who were healthy and at their productive ages. Another shortcoming was that the subjects could not be conditioned ideally in the sense that some strenuous activities associated with the subjects’ physical conditions, primarily the auditory organs, affected the physical conditions and the measurement results.

Authors’ acknowledgments are extended to:
- Prof. Dr. H. Suhariningsih, as Promotor
- Dr. Ir. Totok Soehartanto, DEA, as co-Promotor
- Dr. dr. H. Nyilo Purnami, sp THT-KL(K) as the Head Assistant of ENT (Ear,Nose,& Throat) Division in Dr.Soetomo Regional State Hospital Surabaya-East Java, Indonesia

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