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Technique and Applications of Biofeedback in Photoplethysmography

(For the treatment of migraine)

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Abstract - The correlation of plethysmography with electrocardiography makes us to explore its clinical significance and its application in detection of cardiovascular ailments. But detailed study on plethysmography also helps us to find new methods for therapeutic purpose. One such application is the treatment of Migraine. The technique, procedure, application and biofeedback in Photoplethysmography(PPG) is thoroughly studied and analyzed here.

I. INTRODUCTION

Plethysmography is a test to measure the volume changes in various parts of the body and to check if there are any blood clots or abnormal flow of blood. Photoplethysmography is a non invasive technique to study the blood volume changes in the micro vascular bed of the tissue. It is presently used as a part of many major diagnostic instruments and is used to calculate pulse rate, oxygen saturation, blood pressure and cardiac output. The basic principle is the cutaneous reflection of infra red light from the venous plexi of the tissue. It uses a photo transmitter like an LED to transmit the light and a photo receiver like photodiode or phototransistor to capture the reflected light. The transceiver unit is tied around the thumb or index finger. The change in intensity with and without blood flow is determined and this is converted to voltage by a photo receiver. And then the potential difference is amplified, processed and displayed using ADC and display devices. This is then shown to the patient himself and he recovers by viewing his own body signal and change in the parameters due to abnormalities.

II. PPG SENSOR

It consists of an IR transmitter and receiver which emit the IR light to the tissue and captures the reflected light with greater intensity. The receiver or the photodetector converts the light energy into electrical energy. The blood flows through the tissue periodically. When blood flows through the vessel, there is maximum

reflection and the reflected light intensity is converted to a potential difference by the photodetector.

Fig. 1: PPG Sensor tied around the subject's fingers

The electrical energy or the potential difference so obtained is amplified and processed using a signal conditioning circuit.

III. TECHNIQUE AND PROCESSING

A. Technique Adopted

The pulse rate of the patients can be found using a PPG sensor which is placed usually on the finger such that the transmitter and receiver are close to the tissue which has more blood flow and from which the reflected light can be captured easily. The sensor should be cased in a black box like set up or can be made in the form of a Velcro band as in Fig 1. This is to reduce the light interference and in turn decrease the errors due to artefacts.

B. Processing

The processing mainly deals with the signal conditioning circuit which consists of proper filtering and amplification circuits to get a well defined signal as the output display. There is a Butterworth low pass filter with a cut off around 7 Hz in order to reduce the high frequency interference.

Fig. 2 : Pulse waveform as obtained in the technique

Fig. 3 : FFT analysis of pulse data obtained

The low frequency components may be due to the artefacts which arise due to the faulty instruments or due to movement of the subject, termed as motion artefacts. The PPG sensor is extremely sensitive to these motion artefacts. These can be reduced by means of high pass filter. These low frequency components smear the power spectrum of the PPG signal and can affect the results.

C. Power Spectral Density Estimation

PPG waveform consists of a pulsatile AC waveform which corresponds to the arterial blood volume changes and in turn the cardiovascular dysfunction. The DC waveform corresponds to the change in venous pressure. The dc components need to be eliminated so a linear detrending is applied using MATLAB. FFT spectral analysis was performed on the data and was found to have many spurious peaks as in Fig 3. The normal waveform typically has a peak around 0.1 Hz and 1-1.5 Hz. The spurious peaks are avoided by adopting non parametric signal analysis using Welch method.

IV. APPLICATIONS OF PHOTOPLETHYSMOGRAPHY

A. Cardiovascular System

The Photoplethysmography technique is adopted to estimate many parameters related to the heart and thereby detect many cardiovascular diseases. By using this method we can calculate the heart rate, blood pressure, blood oxygen saturation and cardiac output. It is also used as a diagnostic tool to detect arterial diseases, atherosclerosis, arterial compliances. The DC component of the PPG waveform can be used for the non-invasive assessment of lower limb chronic venous insufficiency (CVI). CVI often results in the reflux of blood through damaged valves in the legs on standing. Changes in the limb blood volume with posture can be tracked with PPG because of the associated changes in light absorption. This approach is sometimes referred to as light reflection rheography (LRR). The vasospastic or cold sensitivity condition known as Raynaud's phenomenon can be investigated using PPG. The pulse amplitude and the slope of the rising edge were good markers for the condition. The PPG signal is composite in nature and has low frequency components relating to respiration, blood pressure control and thermoregulation, as well as the high frequency components relating to the heart synchronous pulse waveform. Changes in pulse with orthostatic stress have been used in the assessment of Orthostasis. The PPG of various subjects during various conditions like stress, running, sleeping and other postures were studied.

B. Biofeedback in Photoplethysmography

Biofeedback is the process of becoming aware of various physiological functions using instruments that provide information on the activity of those same systems, with a goal of being able to manipulate them at will. Biofeedback may be used to improve health or performance, and the physiological changes related to the Biofeedback also seems to be a useful tool in the treatment of a broad range of problems commonly seen by psychiatrists. The adjunctive use of biofeedback is reasonably well-documented for the psychological disorders of anxiety and insomnia changes in thoughts, emotions, and behavior. The main idea of biofeedback is that the subject learns to alter the functions of the body by just monitoring his heart rate, temperature himself. Biofeedback is also a therapeutic tool to facilitate learning self-regulation of autonomic functions for improving health. Photoplethysmograph can provide useful feedback when temperature feedback shows minimal change. This is because the PPG sensor is more sensitive than a thermistor to minute blood flow changes. Biofeedback therapists can use a photoplethysmograph to supplement temperature

biofeedback when treating chronic pain, edema, headache, stress and emotions. Photoplethysmography (PPG) biofeedback machines monitor parameters associated with the heart and can be used to help treat certain types of cardiac arrhythmias

C. Treatment of Migraine

A migraine is caused by abnormal brain activity, which is triggered by stress, certain foods, environmental factors, or something else. However, the exact chain of events remains unclear. Today, most medical experts believe the attack begins in the brain, and involves various nerve pathways and chemicals. The changes affect blood flow in the brain and surrounding tissues.

There are two headaches : Vascular and tension. Migraine is a kind of vascular headache. The blood vessels in the cranial region receive more blood and hence there is a decreased blood supply to the extremities. Both the types of head ache can be treated using biofeedback techniques. The vascular head ache can be treated using PPG biofeedback or Thermal biofeedback while the tension feedback can be treated using EMG biofeedback. But the vascular headache can also result in muscular tension and hence lead to tension headache.

The Thermal biofeedback is so simple. The patient is made to watch or hear his body's response to migraine and is given directions to control himself. He is made to rub his hands and raise the temperature and hence increase the blood flow to the extremities and hence controls the migraine headache by himself. However, it is not a common practice as it showed only minimal changes and had less sensitivity.

PPG Biofeedback was invented to supplement temperature biofeedback. It is more sensitive to small blood flow changes. And it is more useful than the hand warming technique. The temporal artery is behind the eyes and is used to detect blood flow. The blood flow in that artery is reduced and it is found that the blood flow changes are recorded more easily through the temporal artery than that of the other peripheral arteries. The effective treatment of migraine will be a combination of both temperature biofeedback and PPG biofeedback. A temperature sensor is tied around the subject's finger and the temperature is displayed to him through an LCD display. The pulse and heart rate is monitored by means of a photoplethysmograph. The patient sees his pulse waveform and the temperature at the extremities and rubs his hands to compensate the decreased blood flow. And slowly the temperature increases at the extremities and blood flow also becomes normal. By doing this for half an hour three times a week the migraine sufferer

gets the knowledge of getting rid of the pain all by himself. Soon he will not need even the electronic biofeedback machine.

Fig 4: Block Diagram of PPG Biofeedback

V. CONCLUSION

Thus the photoplethysmography technique is used to treat migraine through biofeedback. The method is used to measure the various cardiac parameters like blood flow, heart rate, blood pressure, blood oxygen saturation, cardiac output, microvascular blood circulation and diagnosis of diseases like atherosclerosis, arterial diseases, arterial compliance and vasospastic conditions.

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