COMPARISON OF FFT, AR AND WAVELET METHODS IN TRANSCRANIAL DOPPLER SIGNAL OBTAINED FROM INTRACEREBRAL VESSELS

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Absract **- In this work, transcranial Doppler signals recorded from the temporal region of brain on 35 patients were transferred to a personal computer (PC) via 16 bit sound card. FFT, AR and WT methods were applied to transcranial Doppler for obtaining sonograms. Spectral analysis were obtained in order to compare with three methods in the case of medical diagnosis. The comparison shows that WT method offers better results for the spectral resolution than the other methods. This also leads the determination of brain pressure more accurately.**
Keywords - Transcranial Doppler, Temporal region, sonogram.

I. INTRODUCTION

Transcranial Doppler applications to the adult intracerebral circulation has increased enourmously in the last fifteen years. Transcranial Doppler has been used to evaluate intracranial stenoses and cerebral arterivenous mulformations, in the evaluation of cerebral vasospasm and in the study of cerebral hemodynamics.

In this work, Fast Fourier Transform (FFT), Autoregressive (AR) and Wavelet transform (WT) methods were applied to transcranial Doppler signals obtained from middle cerebral blood vessels. Analysis results show that the bifurcation of cerebral vessel have some structured defectiveness or aneurysm. To investigate the narrowing of vessels, sonogram output were obtained for each patients using the results of analysed signal[1].

II. MATERIALS AND METHOD

The hardware of the system consist of a 2 MHz ultrasound Doppler unit (Multi Doppler Transducer XX, DWL, GmbH, Uberlingen, Germany), a Sony recorder, a PIII 600 MHz microprocessor based personal computer with printer. The analog Doppler unit can work both continuous and pulse wave mode. The sample volume sizes can be adjusted according to vessel diameter for recording different blood flow.

The suitable signal analysis method should meet the following conditions : spectral envelope should be clearly obtained, there should be no noise frequency component in the sonogram, the resolution of sonograms should be high, and finally sonograms should provide some information about blood speed and pressure for the clinicians. Transcranial Doppler signals obtained from middle cerebral artery are sampled and grouped as the

suitable frames. After framing process, power spectral density P(f) of each frames can be calculated using FFT, AR and WT methods. These are combined with side to side to construct the three-dimensional sonograms. In sonogram, horizontal axis represents time *(t)* and vertical axis represents the frequency *(f)*. The gray scale of the diagrams show the power of the frequency component of the graph *P(f)*. As the gray scale turns into black, it means that the power of related frequency component is increasing[2].

Discrete Fourier transform of a discrete time periodic signal is described as the following:

$$X_k = \sum_{n=0}^{N-1} x(n) e^{(-jkn\frac{2}{N})} \tag{1}$$

where X_k is expressed as discrete Fourier coefficients, N is the frame size and $x(n)$ is the input signal on time domain. To obtain the frequency spectrum of this signal, logarithmic values of the squares of absolute values of X_k are found as the following:

$$P(k) = 10\log|X_k|^2 \tag{2}$$

The performance of FFT method becomes insufficient for recording blood flow in the stenosis where the speed of blood is high thus causing turbulences. On the other hand, AR modeling method is suitable for time series that have sudden peaks but not deep hallows in their frequency spectrum.

An AR process x of order p is defined as

$$x(n) = -\sum_{m=1}^{P} a_m x(n-m) + e(n) \tag{3}$$

where $x(n)$ is the array of samples, a_m are the model coefficients and $e(n)$ is the driving white noise which represents the error term. The power spectral density estimation $P(k)$ of the data when the linear prediction extrapolation is used as the following:

$$P(k) = \Delta t \sum_{M=n}^{K-1} r_{xx}(m) e^{j2\pi km\Delta t} \tag{4}$$

where K can be chosen as a power of 2, $r_{xx}(m)$ autocorrelation function. This method does not yield satisfactory results when one wants to observe the effects of sudden fluctuations despite the fact that a good spectral resolution was obtained and misleading frequency components can be found in sonogram. For this reason, Wavelet method was found to be necessary [3].

WT methods provide the window length to get wider and narrower when it is required. The purpose of this

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Abstract

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model is to catch a spectral resolution balance and reduce the number of samples. The WT is being increasingly applied to analyze signals with nonstationary components. If $W(a,b)$ is the WT of a signal $S(t)$, then $S(t)$ can be restored using the formula:

$$S(t) = \frac{1}{C_\psi} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} W(a,b)\psi(\frac{t-b}{a})\frac{dadb}{a^2} \qquad (5)$$

provide the Fourier transform of Wavelet $\psi(t)$, denoted $\psi(t)$, satisfies the following admissibility condition:

$$C_\psi = \int_{-\infty}^{\infty} \frac{\psi(f)^2}{f} df < \infty \qquad (6)$$

III. RESULTS AND DISCUSSION

It is convenient to think of the interpretation of Doppler waveform shapes as a process of pattern recognition. The object of waveform analysis is to recognize those waveforms that are abnormal even if the details of why a particular physiological as pathological change gives rise to a particular change in waveform shape is not fully understood. It is easy to follow the frequency components of Doppler signal by forming into sonogram. The envelope of sonogram is the maximum frequency curve to investigate different vessel diseases.

Transcranial Doppler used for cerebral blood vessels gives insight for temporal region of the patients after surgical operation. In addition, Resistive Index which is used to calculate the cerebral pressure of patient can be determined by using Transcranial Doppler. Resistive Index (R) is used for the obtaining of cerebral pressure is expressed as:

$$R = \frac{Systole\ Density - Diastole\ Density}{Systole\ Density} \qquad (7)$$

In order to calculate the cerebral pressure before and after the surgical operation accurately, the peak and valley of systole and diastole curves should be clearly imaged on the sonograms. Normal resistive index of adults is less than 60%. If the patient is in aneurysm, then carotid blood velocity causes high blood velocity in middle cerebral vessel of temporal region. For this reason, the difference of systole and diastole on sonogram curve belonging aneurysm patient is high.

Figure 1a, 1b and 1c show FFT, AR and WT sonogram of 58-year old patient who is in aneurysm in cerebral vessel, respectively.

The first peak between 2.5 - 3 kHz (systole) and second peak between 1 - 1.5 kHz in Figure 1a (FFT sonogram) are not clear according to Figure 1b (AR sonogram) and Figure 1c (WT sonogram). The reason of this, there is sudden changes with 1s duration.

In order to assume the transcranial Doppler is stationary for the FFT application greater than 10s, frame size should be decreased. When the frame size is decreased, the performance of FFT is also decreased. This causes the spectral broadening and less frequency resolution. AR sonogram is Figure 1b gives better result in the case of frequency resolution when frame size is small. Since the patient is in aneurysm, there is turbulent flow. This means that the signal is nonstationary. In this case WT method gives better results as shows in Figure 1c.
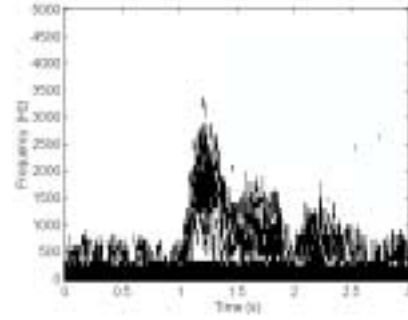

Figure 1 (a) Doppler sonogram recorded from 58 year old atient having aneurysm, FFT method
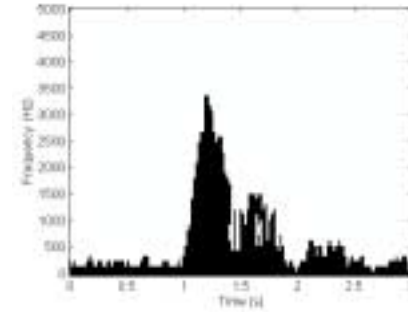

Figure 1 (b) Doppler sonogram recorded from 58 year old patient having aneurysm, AR method

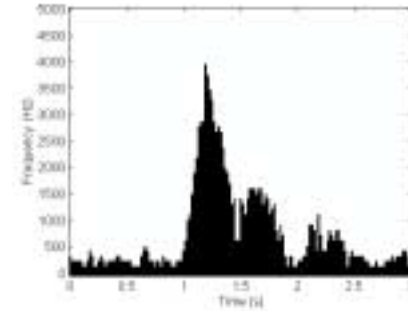
Figure 1 (c) Doppler sonogram recorded from 58 year old patient having aneurysm, Wavelet method

IV. CONCLUSION

The main goal of this work is to increase the spectral resolution of transcranial Doppler signal used for cerebral vessels. This is very useful when blood velocity in cerebral arteries is turbulent. WT method is more powerful for the processing of blood flow signal in cerebral arteries.

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