Statistical Analysis of Wavelet Coefficients of Sural Nerve Conduction Signal in Diabetic and Non-Diabetic Patients

M. J. Godse and N. K. Jog

***Abstract*-- Diabetes Mellitus (DM) affects millions of people all over the world every year. In India alone 35 million persons are suffering from DM. This number is growing day by day. By the year 2025 the number is expected to increase by 60 %. DM leads to various complications such as peripheral neuropathy, cardiac disease, renal failure, etc. which in a number of cases are the main causes of early death. Amongst different complications, the most common complication is autonomic peripheral neuropathy (APN).**

The doctors confirm APN only after conducting the conventional method of measuring nerve conduction velocity (NCV) which is the gold standard. In this paper, NCV is measured on Sural nerve of Diabetic patients. Using DB4 wavelet approximation and detailed coefficients are derived. Average Coefficient Index (ACI) and Summed Coefficient Index (SCI) are calculated from the approximation coefficients. This is a pioneering work, which has not been carried out so far. An attempt is made to find out if a correlation exists between the duration of diabetes and degree of neuropathy. Statistical analysis will be carried out in future, after collecting data of large group of patients.

***Index Terms*—Diabetes Mellitus, Nerve Conduction Velocity , Average Coefficient Index (ACI), Summed Coefficient Index (SCI), Nerve Action Potential (NAP), Wavelet Coefficients.**

I. Introduction

DIABETES Mellitus (DM) was supposed to be one of the old- age diseases, caused and / or detected at the time of retirement in olden days. But today, it is one of the most common diseases [5] detected in younger generations. There may be a number of reasons for this such as, bad food habits, modern life style, genetic inheritance, improper diet, obesity, mental stress, lack of physical activity – exercise, etc. Looking into the increasing figures of diabetic patients day by day, the need for prevention and early detection of DM and its complications thereafter has become a major concern. One of the most common complications caused by DM is autonomic neuropathy. It typically presents late in the course of diabetes and is generally accompanied by other features of distal sensorimotor poly-neuropathy [1].

Diabetic Peripheral neuropathy (DPN) is a frequent micro-vascular complication of diabetes. The Rochester Diabetic study has shown that 54 % of patients with type 1 and 45 % with type 2 diabetes mellitus (DM) had poly-neuropathy [2] . Most of the diabetic poly-neuropathy involves sensory, motor and autonomic nerve fibres.

The objective of this study is to analyze Nerve Conduction Velocity studies (NCS) for diabetic and non-diabetic patients with neuropathy. NCV is the gold standard for DPN detection. As per the standard procedure, NCV signal recordings on sural nerve are carried out [4] by placing electrodes on posterior to lateral malleolus. In this project, the approximation and detailed wavelet coefficients of these signals were derived using Daubechies DB4 wavelet. Average Coefficient Index (ACI) and Summed Coefficient Index (SCI) were found to be proportional and could be used for representing amplitude of the original signal.[10]

II. NCV PROCEDURE

As a preliminary study a data of 3 patients (2 diabetic and 1 non-diabetic) was taken for trial and an attempt is made to find out if there exists a correlation between age and stimulus required for optimum response. At the time of actual NCV recording, the subjects will be made comfortable by explaining them the procedure of NCV and giving them an idea of the objective of this study. Patient history will be noted along with other details, such as the age of the patient and the date of detection.

A. Instrumentation

Computerized EMG machine will be used for the recordings the NCV of the patients. Data of 3 patients was recorded for trial. Sampling frequency of 50KHz was used for recording purpose. Signals were saved in text form and text files were transferred on a removable device using export option. Same procedure will be followed in future for this research.

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B. Electrode Placement

Disposable needle electrodes were used for recording the Nerve Action Potential NAP. As per the standard procedure, the sensory studies of the sural nerve are performed by placing the active recording electrode posterior to the lateral malleolus and reference electrode 4 cms distal towards the lateral aspect of the foot [4]. The ground electrode is placed just proximal to the active electrode. Sural nerve is stimulated by placing the stimulating electrodes on the posterior portion of the calf 14 cms from the active electrode or more than 14 cms depending on the height of the patient. Voltage stimulus is applied according to the requirements to obtain a proper response. Patients with advanced neuropathy require a higher stimulus.

C. Nerve Response

NAP was recorded as the response of the sural nerve to the stimulus applied. This signal was read from the text file and plotted. NAPs of 3 sample patients plotted are as shown in fig. 1, fig. 2 and fig. 3. Patients 1 and 2 are diabetic and 3 is non-diabetic.

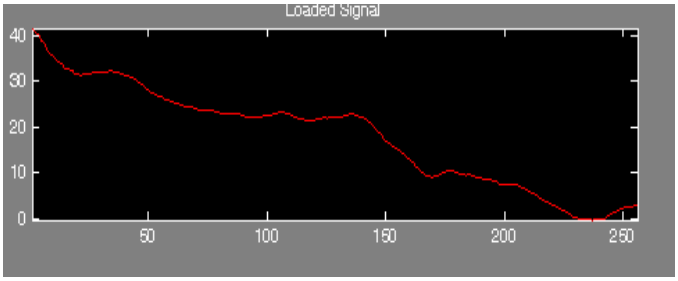

Fig. 1: Nerve Action Potential recorded on Sural Nerve of diabetic patient 1

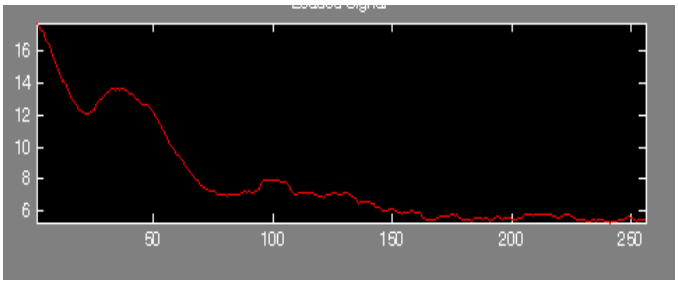

Fig. 2: Nerve Action Potential recorded on Sural Nerve of diabetic patient 2

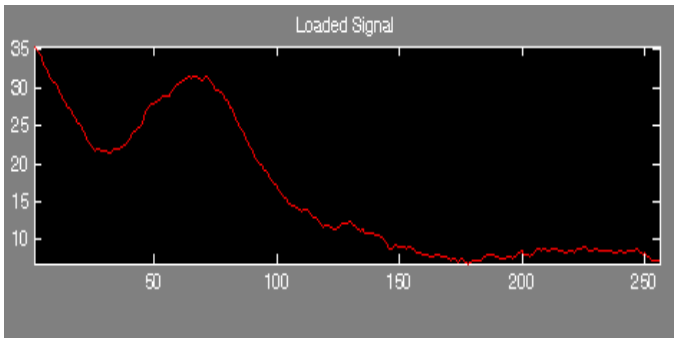

Fig. 3: Nerve Action Potential recorded on Sural Nerve of a non-diabetic patient 3

III. SIGNAL PROCESSING

A. Wavelet Coefficient Index

Usually, wavelet transform is used for denoising of signals and compressing the signals, thereby reducing the size of the sample points and transmitting the signals [11]. In this project, Daubechies 4 (DB4) wavelet was used to derive

approximation wavelet coefficients (awc) . Statistical analysis was carried out. SCI and ACI i.e. mean were calculated [10].

1) Summed Coefficient Index (SCI)

It is expressed as

$$SCI = \Sigma\, awc_i \qquad (1)$$

Where awc represents the approximation wavelet coefficients and i represents the level of decomposition.

2) Average Coefficient Index (ACI)

It is expressed as

$$ACI = \frac{\Sigma\, awc_i}{n} \qquad (2)$$

Where awc represents the approximation wavelet coefficients, i the level of decomposition and n number of coefficients at that particular level of decomposition.

B. Software

MATLAB 7.0 was used to process the data [9]. An algorithm was developed to calculate SCI and (ACI) i.e. mean of the approximation coefficients of the signal. Statistical analysis was carried out on the wavelet coefficients [10]. Mean (ACI), median and mode [8] of the approximation coefficients at seven levels of decomposition were derived. The levels of decomposition depend on the number of sample points, which was 2000 in the current data. Level of decomposition can be extended to 10 also.

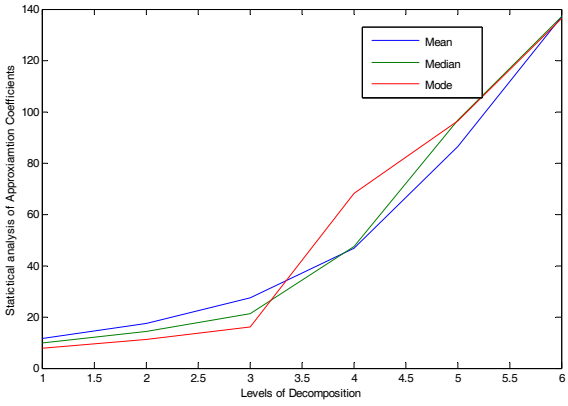

Fig. 4: Mean (ACI) , Median and Mode of approximation coefficients versus levels of decomposition of diabetic patient 1

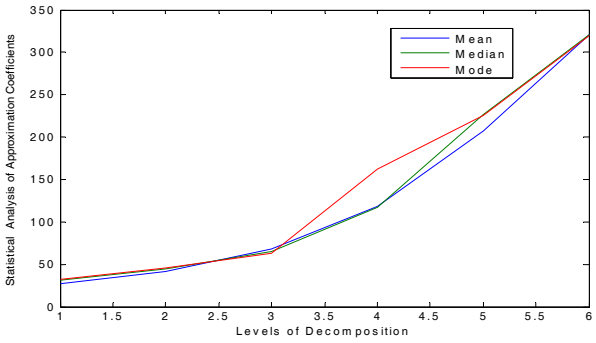

Fig. 5: Mean (ACI) , Median and Mode of approximation coefficients versus levels of decomposition of diabetic patient 2

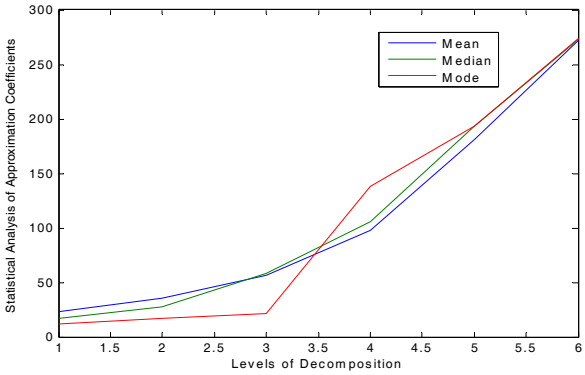

Fig. 6: Mean (ACI) , Median and Mode of approximation coefficients versus levels of decomposition of a non-diabetic patient 3

Graphs of (ACI) mean, median and mode versus levels of decomposition were plotted for patient 1, 2 and 3 respectively as shown the figures fig. 4, fig. 5 and fig. 6. Scalograms were also plotted respectively as shown in the figures fig.7, fig.8 and fig. 9 using this software [3],[6],[9].

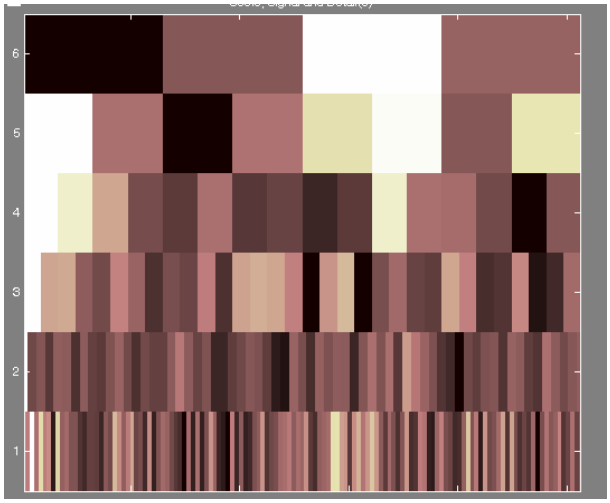

Fig. 7: Scalogram of diabetic patient 1

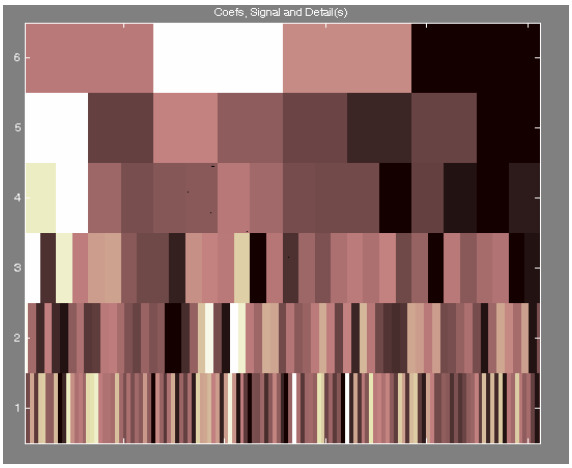

Fig. 8: Scalogram of diabetic patient 2

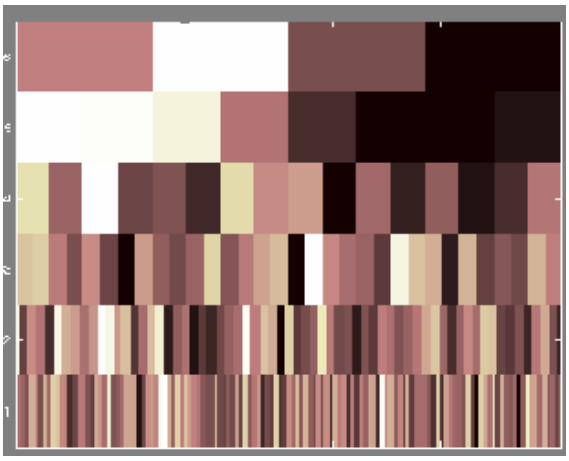

Fig. 9: Scalogram of a nondiabetic patient 3

Patient	Age	Latency	Stimulus
Diabetic Type 2 Patient 1	43 yrs	3.50 ms	102 V
Diabetic Type 2 Patient 2	46 yrs	3.95 ms	178 V
Non-Diabetic Patient 3	19 yrs.	3.15 ms	97 V

Fig. 10: Table of applied stimulus and latencies

IV. RESULTS

As seen in the graphs, the mean and median of the approximation coefficients followed a similar pattern to certain extent, whereas mode followed a different pattern. After level 2 of decomposition, mode rises in all the three patients.

Scalograms represented the amplitude of the approximation and detail coefficients. The light spots represented the highest amplitude.

It can be concluded from table shown in fig.10, that diabetic patients require a large amplitude stimulus as compared to non-diabetic and the latency period is also longer for diabetic patients.

V. CONCLUSION

Statistical analysis of approximation coefficients and detail coefficients may be useful for analysis of progress of neuropathy and its early detection. As mentioned in the results, the graphs of mean, median and mode indicated different patterns.

Main aim of this study is to try and establish a relationship between the nature of results with age of patient and date of detection of diabetes. After collecting data of several diabetic patients of various groups, early detection of neuropathy could be predicted.

VI. REFERENCES

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VII. BIOGRAPHIES

Manali Godse was born in Mumbai in India, on Feb 19, 1972. She received B.E degree in Biomedical Engineering from University of Mumbai, in 1993. She also received M.Tech degree from IIT Powai, Bombay in 1999. Currently she is pursuing her Ph.D in Diabetic Neuropathy in Electronics Department of Mukesh Patel School of Technology and Engineering under NMIMS (D.U) under the guidance of Dr. N. K. Jog. She has also enhanced her knowledge in management skills by acquiring a Diploma in Business Management from Prof. Welingkar's Institute of Management, Mumbai.

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Nandini Jog has received her B.Tech (Hons) in Electrical Engineering from IIT Bombay in 1966 and M.E in 1983 and Ph.D (Tech) in 1993 from VJTI Bombay University. Her Ph.D is in Electronic Music. She has worked as lecturer (1977-1986), as Professor (1996-2003) in VJTI. She joined Sardar Patel College of Engg. As a Professor and Head of Electronics Dept (2003-2005). She headed Sardar Patel Institute of Technology as the principal (2005-2006). She has 32 years of teaching experience. She has published seven books on Electronics Engg. She has own several awards in academics, sports and Hindustani classical vocal music. Currently she is working as a Professor and Head of Electronics Department of Mukesh Patel School of Technology and Engineering NMIMS University . She is a recognized guide for Ph.D in NMIMS university, Mumbai University and in Symbiosis Unversity.