Evaluation Of The Role Of Visual Evoked Potentials In Detecting Visual Impairment In Type II Diabetes Mellitus

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Purpose:- To investigate the visual evoked potentials in Type II diabetic patients in order to determine the alterations, if any, resulting from visual impairment due to diabetes mellitus (DM).

Material & Methods:- The study was conducted in the Neurophysiology unit of the Department of Physiology of a rural medical college of Central India. The study population consisted of 30 patients diagnosed with Type II DM and 30 age matched controls after proper screening as per inclusion and exclusion criteria. Both eyes of the two groups of the subjects were included in the study.

Design:- Tertiary care rural hospital based, single time assessment, short term observational study.

Methodology:- The stimulus configuration consisted of the transient pattern reversal method in which a black and white checker board is generated (full field) on a VEP Monitor by an electronic pattern regenerator inbuilt in an Evoked Potential Recorder.

Results:- Mean age of Type 2 diabetic subjects was 58.21 ± 8.17 years and it was 54.48 ± 3.87 years in controls. Except N70 Latency of LE, there was a statistically significant difference between diabetic subjects and controls in terms of all the PRVEP parameters of both the eyes (P<0.001). The pathological VEP was recorded as significant prolongation of P100 latency and significant lower amplitude in diabetic patients compared to control group. A significant intra-ocular difference was observed in 20% cases. The differences between the three groups namely diabetics with diabetic retinopathy (DR), diabetics without DR and controls using One-way ANOVA were statistically significant in terms of P100 and N155 latencies and P100 amplitude (P<0.001), with the exception of N70 latency.

Conclusion:- P100 wave latencies were significantly delayed in the diabetic patients compared with the control subjects indicative of functional disturbances in the visual system related to glucose metabolism.

Introduction
Visual evoked potential (VEP) test evaluates how the visual system responds to light. As it tests the function of the visual pathway from the retina to the occipital cortex, VEP is a useful clinical tool in the diagnosis and documentation of visual impairment in many ophthalmological disorders. Diabetes is rapidly gaining the status of an epidemic in India with more than 62 million people diagnosed with the disease. At this rate it is predicted, by 2030, the number of diabetics would go up to 79.4 million. Thus, the prevalence of Diabetes is growing leaps & bounds. The prevalence of diabetes mellitus (DM) in adult populations is 6.6% worldwide.

Diabetes mellitus, being a silent killer, despite the progress in therapy causes various complications including visual impairment which may ultimately progress to blindness. It affects the retina causing diabetic retinopathy which may result in irreversible blindness. Optic neuropathy manifesting as optic atrophy due to DM alone is estimated to occur in about 0.6% of cases. It is related to the duration and control of diabetes. If detected timely it can be managed by laser treatment. Annual Eye checkup and screening for diabetic retinopathy is necessary to detect the onset. With timely screening and treatment 80% of blindness due to diabetic retinopathy is “avoidable”. Knowing about the neuropathy associated with DM, it is pertinent to expect dysfunction to occur along the visual pathway right from the retina. Diabetic retinopathy is usually considered to be a disease of retinal blood vessels but is rarely thought of, in a wider sense, as a neurosensory disorder. Changes in the retina caused by diabetes may lead to visual impairment in dim light, even with good visual acuity and visual fields. Although abnormalities within the peripheral nervous system are well documented in diabetes, changes within the central nervous system, and particular their relationship to visual function, have received much less attention. Prior to the onset of microvascular lesions, the neural retina of diabetic eyes undergoes subtle functional changes which are not detectable by fundus photography. Functional exploration of the optic pathways with pattern reversal visual evoked potentials (PRVEPs) has been accepted as a non-invasive method of investigation of diabetics long back. Analysis of pattern reversal VEPs may provide early diagnosis of such diabetic changes and determine prognosis during treatment. The extent of visual system involvement in diabetes has only recently been realised because of dearth of neurophysiological techniques in the past and study of objective testing of optic nerve function in diabetic population has not been attempted so far in this part of the country. Our study was intended to

Keywords: Pattern reversal VEP, Type II Diabetes Mellitus, Diabetic Retinopathy.

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explore the utility of this low cost, less time consuming, non-invasive yet objective tool to unveil those visual defects which remain obscure on ophthalmoscopy so that the major chunk of diabetic patients could be rescued before falling prey to diabetic retinopathy because unfortunately, in many of the diabetic cases, the patient remains asymptomatic until it is too late for effective treatment.

**Material & Methods**

**Type of study:**
This was a tertiary care rural hospital based, non-invasive, non-interventional, single time assessment, short term observational study.

**Study participants**
The study population consisted of 30 patients of type II DM after proper screening as per inclusion and exclusion criteria. Both the eyes of the subjects were included in the study.

**Study Setting**
The study was conducted in Neurophysiology unit of the Department of Physiology of a rural medical college located in central India. All subjects underwent a complete ophthalmological examination including measurement of best corrected visual acuity, slit lamp biomicroscopy, direct and indirect ophthalmoscopy and fundus photography after obtaining a complete history including duration of diabetes and latest fasting blood glucose level in diabetic patients.

**Inclusion Criteria**
- Patients diagnosed as having Type 2 diabetes mellitus by consultant physician
- Best corrected visual acuity 6/6 or better
- No significant history of alcohol or smoking
- Willing to give informed consent

**Exclusion Criteria**
- Significant ocular disorders, cataract, glaucoma, optic nerve disease, macular disease
- Lens/ corneal opacities, miotic pupil
- Best corrected visual acuity less than 6/6, amblyopia
- Recent eye medications (mydriatics or cycloplegics in the past 12 hours)
- Patients with serious systemic illness affecting the performance of VEP
- History of head injury or having undergone recent neurosurgery.
- Not willing for study participation or whosoever refused to be a part of study.
- Any unco-operative or febrile patient.

Data were compared with clinical measures, age at onset, duration of disease, and glycemic control. Physical parameters including height, weight, occipito-frontal circumference were also measured. All the subjects were investigated for transient pattern reversal Visual Evoked Potential (PRVEP) in the Department of Physiology.

**Method:**
VEP recordings were done in accordance to the standardized methodology of International Federation of Clinical Neurophysiology (IFCN) Committee Recommendations and International Society for Clinical Electrophysiology of Vision (ISCEV) Guidelines and montages were kept as per 10-20 International System of EEG Electrode placements. The reference electrode (Fz) was placed 12 cm above the nasion, the ground electrode (Cz) at the vertex and the active electrode (Oz) at approximately 2 cm above the inion.

**Instrument:**
The stimulus configuration for VEP recording was transient pattern reversal method in which a black and white checker board will was generated (full field) on a VEP Monitor by an Evoked Potential Recorder (RMS EMG EP MARK II). RMS EMG EP MARK II manufactured by Recorders & Medicare Systems, Chandigarh). The rate of pattern reversal (1.7 Hz), the size of the checks (8x8), the luminance (59cd/sqm.) and contrast level (80%) were kept constant for all the recordings in all the cases and controls. The recording was done monocularly for the left and right eyes separately with the subject wearing corrective glasses, if any during the test.

**Subject Preparation**
- Each subject was briefed previously about the procedure to alleviate any apprehension and to assure full relaxation during the test.
- Standard disc EEG electrodes were placed on the scalp areas after preparing the skin by degreasing and abrading with a conducting jelly or electrode paste (RMS recording paste) rubbed lightly into the area with a cotton swab to ensure good, stable electrical connection.
- The subject was seated comfortably at a distance of 1 meter away from the screen of the VEP monitor so that accommodation of the eye was relaxed.

**Procedure of VEP recordings**
1. The recording was done in air conditioned, sound attenuated, darkened room. The only source of light was the stimulus itself.
2. After controlling all factors that influence the VEP pattern, the subject was instructed to close one eye with black blinders on the eye and to fixate his other eye on a small red dot at the center of the screen of the VEP monitor, on which black and white checker board pattern was generated full field.
3. The signals recorded were filtered (low cut and high cut frequency filter) through a band spread of 2-100 Hz.
4. The sweep duration was maintained at 300ms. Responses to 200 stimuli were amplified and averaged for each eye, which were then analyzed by inline computer having automatic artifact rejection mechanism.
5. A minimum of two records for each eye were obtained and superimposed on one another to ensure replicability of the VEP pattern.

**VEP Waveform**
The usual PRVEP waveform is the initial negative peak (N70), followed by a large positive peak (P100) and followed by another negative peak (N150). Positive wave P100 is shown with downward polarity and the negative waves are shown with upward polarity in the recording. P100, the hallmark of
full field VEPs, is the most consistent and least variable peak compared with N70 and N155 and maximal at mid-occipital electrode. Since the P100 latency is one chief discriminator between normality and abnormality of the visual pathways, major emphasis is laid upon P100 wave and its latency and amplitude measured from the averaged waveforms.

**Ethics Consideration:**
The study protocol was approved by the Institutional Ethics Committee and written informed consent was obtained from all subjects.

**Statistical analysis:**
All data was abstracted on a standardized data collection form. Data was analysed using SPSS software, version 21.0 (SPSS Inc., Chicago, USA). Continuous variables were presented as mean ± standard deviation (SD) for normally distributed data compared using Student’s t-test. Spearman’s correlation and coefficient and One-way ANOVA was also utilized for analysis. A P value <0.05 was regarded as being statistically significant.

**Results**
Overall 30 patients diagnosed as having type II DM and 30 control subjects were investigated. The study participants did not differ from each other with respect to their mean age as indicated in Table 1. As shown in Table 2 & 3 depicting comparison of VEP parameters in the right eyes and left eye of patients and controls, except N70 Latency of LE, there was a statistically significant difference between diabetic subjects and controls in terms of all the PRVEP parameters of both the eyes(P<0.001). The pathological VEP was recorded as significant prolongation of P100 latency and significant lower amplitude in diabetic patients compared to control group. A significant difference between the latencies from both eyes was observed in 20% cases. The mean N70 Latencies in the right & left eyes among the two groups have been graphically represented in Figure 1. The mean P100 Latencies in the right & left eyes among the two groups have been represented in Figure 2. The mean N155 Latencies in the right & left eyes among the two groups have been graphically represented in the Figure 3. The mean P100 amplitude in the right & left eyes among the two groups have been graphically represented in the Figure 4. Spearman’s test revealed no statistically significant correlation between abnormal VEP wave amplitude or latencies, and level of glyemia, and the duration of diabetes mellitus. One-way ANOVA was used to test significant differences between the three groups namely diabetics with diabetic retinopathy (DR), diabetics without DR and controls. Their comparative analysis of left and right VEP parameters is shown in Tables 4 and 5. Differences between diabetics with and without DR was statistically significant in terms of P100 and N155 latencies and P100 amplitude (P<0.001) with the exception of N70 latency.

**Figure 1:** Graphical Representation of N70 Latency in diabetic group and in control group

**Figure 2:** Graphical Representation of P100 Latency in diabetic group and in control group

**Figure 3:** Graphical Representation of N155 Latency in diabetic group and in control group
Abnormalities in visual evoked potentials have been described in DM in some previous studies\textsuperscript{12-14}, but there has been tremendous variation in the proportion of patients with increased P100 latency ranging from 9% to 77%. This high variability could be due to a number of factors, like inclusion, the presence of retinopathy or peripheral polyneuropathy and differences in stimulus recording conditions.

We obtained pathological VEP type II DM which manifested as significant (p<0.05) prolongation of P100 latency and reduction in amplitude in 23.33% diabetic patients compared to control group. A significant interocular difference between the latencies was observed in 20% cases. These results are comparable to the findings of Szabela et al\textsuperscript{15} who examined 41 diabetic patients, aged 35 to 62 years and recorded VEP four times, each time using a pattern made up of elements of another size (18, 36, 72 and 144 angular minutes). They obtained abnormal VEP in 22% of the cases. The abnormal VEP recordings with a single size pattern were in 8% to 14% of the cases. The P100 latency increased in 33% of the pathological recordings and in about 66% of the cases there was a significant difference between the latencies from both eyes.

Prolongation of P100 latencies observed in diabetics represents an evidence of structural damage at the level of myelinated optic nerve fibers. This may be due to various pathogenic mechanisms underlying visual pathway.
involvement. Probably it is multifactorial, involving metabolic and vascular factors where ischemia and reduced protein synthesis may result in diabetes induced axonal loss. Our results also imply that there is a definite neurological deficit in type 2 DM which can involve the visual system at a much earlier stage. Accumulation of neural mediators probably encumbers the conduction in the visual pathway, which may produce the observed delay in latencies found in diabetic subjects as compared to healthy controls. It may also be attributed to a reduced velocity of nervous conduction in the optic nerve. This observation is supported by the results of other researchers as well. Many other studies have reported varied percentages of diabetic subjects with abnormal VEPs. Puvanendran et al12 compared the responses of 16 diabetics with a group of 35 healthy subjects; the latency was increased by more than one standard deviation in 13 diabetics (81%) and by more than three standard deviations in 10 diabetics (62.5%), often associated with marked reduction in amplitude. Millingen et al16 proposed that abnormal PVEPs could reflect papillomacular bundle or optic nerve involvement. A notable increase in negative wave latencies was obtained in our study similar to Yaltkaya et al17 who also found prolongation of N140 latency and N90-N140 interpeak latencies as well as increased P100 latency. They explained these findings by the presence of retrochiasmal involvement. Bartek et al18 found pattern VEP abnormalities in 77% of diabetic patients and reported that abnormalities did not correlate with the level of retinopathy. Visual evoked potentials (VEPs) were assessed by Algan et al19 in 50 adult type I (insulin-dependent) and 19 type II (noninsulin-dependent) diabetes mellitus patients and in 54 controls. P100 wave latency was significantly longer in diabetic patients as reported by them. 28% of diabetic patients had P100 wave latencies above the normal range. There was no correlation between P100 latency and type or duration of diabetes mellitus, quality of metabolic control, or presence of degenerative complications. Mariani et al20 reported prolongation of P100 latency in 35 diabetic patients who did not have retinopathy. In the study by Lanting et al21 who investigated P100 latency in 42 diabetic patients, the latency was increased in 19% of subjects. They found no correlation between diabetic retinopathy and P100 latency. Ziegler et al22 recorded VEPs in 12 poorly controlled diabetic patients (7 with insulin-dependent diabetes mellitus and 5 with non-insulin-dependent diabetes mellitus) before and after at least 3 days of normoglycemia. They also reported similar findings. The P100 latencies were longer in their diabetic patients also when compared with control subjects. Four of their 12 diabetic patients had abnormal VEPs as opposed to 27% of the type II DM in our study with improper waveforms. To study the possible progression of neurological abnormalities over time and to evaluate the role of PRVEP alterations in predicting stability and severity of diabetes-related optic disorder, a longitudinal study in 18 non-insulin-dependent diabetic patients and 35 controls was performed by Moreo23 at baseline and again after 4.6±0.8 years. He also found that P100 wave latency increases in diabetic patients just similar to our study and concluded that changes in PRVEPs were stable over time. The study by Verrotti et al24 in 30 young patients with newly diagnosed IDDM revealed that the P100 latency was significantly delayed in patients with diabetes compared with the control group (p<0.01), while the N75 to P100 amplitude was similar in both groups. The percentage of cases with abnormally raised PRVEP latencies were 11.1%, in type II DM as reported by Das et al24 who investigated 57 insulin dependent (IDDM) and non-insulin dependent (NIDDM) diabetic patients and 25 controls with various neuroelectrophysiological tests including VEP.

The abnormal rate of VPEPs in patients with NIDDM was reported by Li and Yang25 as 58.33%, and the latency of P100 was markedly prolonged, wave-forms in their study were poor-differentiated, and the amplitudes of waves were low. Our patients with type II DM without retinopathy demonstrated significantly reduced P100 amplitude a finding in corroboration with Lopes de Faria et al26 who recorded VEP’s with sinusoidally modulated vertical gratings at 10 spatial frequencies presented sequentially on a high-resolution monitor in patients with type 1 DM. In non-proliferative diabetic retinopathy, the delay of P100 wave with inconstant presence of the N75 and N135 waves was noticed by Costache.27 In proliferative diabetic retinopathy and its complications important alterations of the evoked responses were also reported. In agreement to this, our study results demonstrated that differences between diabetics without retinopathy and controls were significant regarding P100 and N155 latencies and P100 amplitude (P<0.001) as well as the differences between diabetics with retinopathy and controls were significant in terms of P100 latency and amplitude (P<0.001). We also noted severe VEP abnormalities in patients with PDR and NPDR. Three out 30 diabetics were having Clinically significant Macular Edema (CSME) along with severe PDR. In a recent study, Heravian et al27 observed abnormal latencies in 60% of diabetic patients. It has been reported by Li and Yang25 that PVEP abnormalities correlate with hyperglycemia but we found no significant correlation between blood glucose levels and P100 wave latencies in diabetic patients. There are some conflicting reports regarding correlation between duration of diabetes and P100 wave latencies but we found no significant correlation between the duration of diabetes and P100 wave latencies. Upon observation of PRVEP responses in recently diagnosed cases of our study, we propose that this technique can have a useful role in monitoring the initial phase of diabetic disease, particularly in determining the effects on visual function, being the only ophthalmic tool useful at this stage of the disease. Furthermore, it can be performed whenever a patient with diabetes but without retinopathy shows a worsening of metabolic control, in order to evaluate the impairment of
visual pathways. Our results also indicate that optic nerve involvement may develop in patients with type II DM prior to the onset of symptoms. These findings suggest that early functional abnormalities of the optic nerve can be detected at onset of diabetes, and that glycaemic control reverses these abnormalities.

Conclusion
The study aimed at functional exploration of the optic pathway by assessing the alteration of pattern reversal visual evoked potentials (PRVEPs) in patients with Type II diabetes mellitus and to deduce its value in clinical application. In conclusion, PRVEP latencies in type II diabetes patients with or without diabetic retinopathy was significantly delayed as compared to non-diabetic controls indicative of functional disturbances in visual system related to glucose metabolism. Importantly, even in patients without retinopathy, VEP could detect preclinical neurodegenerative changes within or upstream the retina indicated by conduction delay and reduction in amplitude. It implies that significant and nonselective neuronal visual loss involving the visual pathway precedes the ophthalmoscopically detectable retinopathy in patients with type II DM. Thus, measurement of P100 has been shown to be an important specialized diagnostic tool in assessing the neural pathways relating to visual function and VEP findings may be of use in the detection of early functional abnormalities of the optic nerve at the onset of diabetes so that they may be treated henceforth and so could serve as a major preventive measure for the incurring blindness. VEP changes detected in asymptomatic patients could be a predictor of future symptoms. This study provides good evidence for abnormalities occurring in the P100 response in people with diabetes before the development of overt retinopathy.

Future Perspective
This study helped in establishing the importance of a visual electrophysiological evaluation as a valuable adjunct to detailed assessment of diabetics and provides a decent recommendation for VEP to be a part of their routine examination as it might be a useful marker which may help to probably identify those visual defects which remain obscured on ophthalmoscopy so that the major chunk of diabetic patients could be rescued before falling prey to diabetic retinopathy.

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