Original research

Vibration perception threshold and the law of mobility in diabetic mellitus patients

M. Manivannan, R. Periyasamy, V.B. Narayanamurthy

Biomedical Engineering Group, Department of Applied Mechanics, Indian Institute of Technology Madras, Chennai 600036, India
Diabetic Foot Clinic, Sundaram Medical Foundation, Chennai 600040, India

Article info

Article history:
Received 27 October 2007
Received in revised form 7 August 2008
Accepted 25 October 2008
Published on line 13 December 2008

Keywords:
Diabetic neuropathy
Mobility law
Verdott's law
Two-point discrimination
Sensitivity test
Neuropathy test
Proximal to distal
Geometry law

Abstract

Background: Diabetic neuropathy is a family of nerve disorders with progressive loss of nerve function in 15% of diabetes mellitus (DM) subjects. Vibration Perception Threshold (VPT) is one of the modalities of testing loss of protective sensation. Law of mobility for VPT is well known for normal subjects, but not for diabetic subjects. This is a pilot study to evaluate and plot the law of mobility for VPT among DM subjects.

Methods: We used biothesiometer to find the VPT of several areas in upper and lower extremities for normal and diabetic subjects. VPT of normal and diabetic subjects for different foot areas from proximal to distal is evaluated for 30 subjects. All the subjects are screened for peripheral artery occlusive disease with ankle brachial pressure index (0.9 or above). VPT values of different areas are arranged in a proximal to distal order for the analysis.

Results: VPT values monotonically decrease from proximal to distal areas. Vierodt's law of mobility holds well for normal subjects in both feet areas. The law of mobility does not hold good for the DM subjects in one or both feet areas.

Conclusions: The VPT value of diabetic subjects reveals that the law of mobility does not hold good for diabetic subjects in foot areas. Though the number of subjects is small, all the subjects defied the law.

© 2008 Primary Care Diabetes Europe. Published by Elsevier Ltd. All rights reserved.

1. Background

Evaluation of sensibility on the feet of diabetic patients is the important factor in order to provide proper identification of the group with neuropathy and to establish prevention of ulceration for those at risk. Objective assessment of peripheral nerve function, whether by traditional neurological examination or by sophisticated techniques using computers, is laborious and time consuming, and a simple, rapid, and reliable test is needed to diagnose peripheral neuropathy in busy outpatient clinics. Measurement of the Vibration Perception Threshold (VPT) with electromechanical devices such as a biothesiometer has been claimed to fulfill this need. Routine neurological examinations such as light touch and pinprick sensation, though commonly used to test for neuropathies, have been found to be less sensitive to diagnose diabetic neuropathy than vibration perception threshold testing. A study
of diabetic type 2 patients showed that the VPT was elevated in 65% of the patients with sensory complaints but also in 20% of the patients without sensory complaints [1].

Normal ranges based on the (VPT) have been published in numerous studies with the suggestion that they could be used clinically to diagnose and monitor peripheral neuropathy. Wide variability in VPT at different sites in the same subject has also been noted [2], especially as many investigators have taken measurements at single or unilateral sites. In this paper we examined the variability in VPT among sites in diabetic and non-diabetic subjects.

Specifically, we introduce law of mobility for VPT, in order to improve the diagnostic accuracy of diabetic neuropathy. The law is well known in neuroscience literature for normal subjects, however it is not known for diabetic subjects. This paper presents the first systematic study of the law of mobility to assess the sensitivity on diabetic subjects, comparing the law of mobility of VPT in the upper and lower extremities of diabetes mellitus (DM) patients. In our earlier work we have shown that the law of mobility for two-point discrimination (TPD) does not hold in diabetes subjects. Similarly, we observe in this paper that the law of mobility of VPT does not hold in DM patients also.

1.1. Law of mobility

Research on cutaneous sensibility was undertaken in the 19th century by Weber [3] and Vierordt [4]. Weber introduced the point localization test initially and the accompanying measures: the TPD and the localization error as a measure of cutaneous sensibility. Density of mechanoreceptors in an area determines the TPD. A dense population leads to finer TPD and the receptors have smaller receptive fields. Mapping of the whole body revealed large differences in the sensibility between different parts of the body. Vierordt generalized this observation to the law of mobility, which states that the TPD improves from proximal to distal body parts. In other words, TPD correlates with the degree of freedom (DOF) of the body part, or extend with which the body part involves (mobility) in an exploration. It is to be noted that no exception to this law has been found yet. Sensitivity decreased from distal to proximal regions, and thresholds correlated with the relative size of cortical areas subserving a body part.

1.2. Vibration perception threshold

The relationship between elevated vibration perception threshold and diabetic neuropathy has been documented for almost 100 years. Impaired vibration sense is an early sign of neuropathy; hence its assessment is an important element of the neurological examination of the patient with diabetes. Vibration perception sensitivity reflects disturbances in the function of fast adapting mechanoreceptors and of thick myelinated sensory nerve fibers. Both are commonly affected in diabetes. VPT measurements using a biothesiometer have been demonstrated to be reproducible under different levels of blood glucose, at different hours of the day, ambient temperature, and skin temperature. It has been shown that increased disease duration leads to significantly higher VPT readings in diabetic patients and that VPT has a significantly higher specificity than other neuropathy score [25–29].

It has been demonstrated that VPT shows twice the prevalence of abnormality compared with clinical examination or clinical evidence of neuropathy [26,27]. VPT is a good predictor of the long-term complications of diabetic peripheral neuropathy. While some clinics only test the great toe for sensitivity and specificity for VPT to determine LOPS, other studies have shown that there is a great variability between testing sites. In addition, studies have shown that variability between sites was significantly greater in the diabetics than the non-diabetic subjects [4–8,32–36,2].

2. Methods

We used a digital Biothesiometer for measuring VPT, which vibrates at 50 Hz frequency, indicating the amplitude of the vibration in a 0–50 V scale.

We measured VPT in foot areas. Although in literature the foot is divided into ten standard significant areas as shown in Fig. 1(a) as per method indicated in [37,38], for our analysis, we have divided the foot into four areas as shown in Fig. 1(b). Hind foot combines area 1, 2, mid foot combines area 3, 4, fore foot combines area 5, 6, 7, and the big toe is area 8.

We evaluated vibration perception threshold on the feet of 30 subjects. VPT values for the normal subjects were collected from the literature and also five normal subjects were included in our study. Twenty-five other subjects were DM patients. The scatter plot of the age of the DM subjects is shown in Fig. 1A. The age ranges from 48 to 58 years. The duration of the diabetics ranges from 1 to 14 years. Only one of the subjects had clawing in the toe, that too on both the legs. Five subjects had callosity in one of the areas of either one foot or both feet.

The patient is first placed in a comfortable reclining position with eyes closed. SWMF (10 gm) is then used on the different areas of the foot to find the sensation and then biothesiometer is used to find the VPT. First, the patients were shown the vibration by gradually turning the amplitude from zero to maximum, then the test began again from zero and they were asked to state whenever they felt the vibration first. Measurements were made on the planter aspect of the big toe bilaterally, three times consecutively for each big toe. The median of three readings is accepted as the VPT value in volts of that measurement. The values indicate the amplitude of vibration, which is proportional to the square of the applied voltage.

Fig. 1 – (a) Standard division of foot area and (b) division of foot area for our study.
Study period was from January’08 to March’08. Total of 30 subjects were tested and the details of diabetic subject is given below in Table 1. All the subjects were screened for peripheral artery occlusive disease (PAOD) with the ankle–brachial–blood pressure index (0.9 or above).

3. Results

The VPT results for 25 DM subjects and 5 normal subjects are shown in the following Figs. 2–6. The graphs show the mean and standard deviation (S.D.) value of VPT. Figs. 2 and 3 show the VPT for normal subjects in hand and foot areas, respectively. The mean of the VPT values obey the law of mobility in both the hands and feet areas. It can be noted that the VPT of the fingers is smaller than that of the palm which in turn is smaller than that of the forearm. Similarly in the foot areas, the big toe has the smaller VPT values compared to that of the fore foot, which in turn is smaller than the hind foot area. Not only the mean VPT of all normal subjects obey the law, but also for every individual subject in both the hands and feet areas, this is shown in Fig. 4.

Mean of the VPT values for the 25 DM subjects are shown in Fig. 5. It can be noted that the VPT values do not obey the law of mobility. The VPT of big toe is biggest compared to that of other areas in both the feet. The big variance of the VPT values among the diabetic subjects shows the wide variation of the years of diabetics among the DM subjects.

Fig. 6 shows an example VPT value for an individual DM subject. For this subject the VPT values do not decrease monotonically from hind foot to big toe, in both the feet. Even though the VPT values of this subject is within the normal range in all the foot areas, the law of the mobility hints, as is not respected, about the diabetic condition of the subject. Law of mobility along with the VPT could therefore be used to improve the diagnostic accuracy of the VPT test alone, which is already well established. VPT values for every DM subject fail to obey the law of mobility, at least in one of the foot areas.

4. Discussion

Though the VPT values in all the above graphs are mean and S.D. of subjects, the law of mobility does not obey even for a single DM subject. This is true for both right and left foot for
The perception of vibration in the 50–300 Hz range principally reflects the activation of mechanoreceptors (i.e. pacinian and Meissner corpuscles). The very nature of the temporal component of the vibrating stimuli, as opposed to simple mechanical pressure, requires high-fidelity afferent conduction and is thus sensitive to multiple aspects of a distal axonopathy.

It has been shown that patients with a VPT < 15 V have had a cumulative incidence of foot ulceration of 2.9% compared with 19.8% in patients with a VPT > 25 V. The average individual with reduced vibration detection (>25V) is estimated to incur approximately five times more direct medical costs for foot ulcer and amputations than an average individual with normal VPT (<15V) [30,31]. Our experiments show that even if the VPT values of the both the feet are well below the normal range of 15 V, the law of mobility could reveal the underlying neuropathy, improving the specificity. About 33% of the DM subjects had VPT values below 15 V in both the feet.

In this paper we have presented the law of mobility only for VPT in DM subjects. In our earlier work, we have shown that the two-point discrimination (TPD) does not obey the law of mobility in DM subjects as well [9]. The other sensory measures such as cold detection threshold (CDT), warm detection threshold (WDT), and heat pain onset threshold (HPO) could be studied for the law of mobility, specifically in DM subjects.

As an extension to our earlier work, we compared the VPT values and TPD values of proximal foot areas for seven normal subjects. Their mean values are shown in Fig. 7. It could be noted that the VTP values and TPD values are highly correlated (Pearson product-moment correlation coefficient is 0.955).

It has been shown by numerous investigators, that a reduction or impaired blood flow and the resultant endoneurial hypoxia are important factors underlying nerve conduction deficits. There is strong correlation between NCV and VPT testing, and research has shown that these tests can predict foot ulceration and death in diabetes [10–15]. Studies have demonstrated that there is a good correlation between the degree of microangiopathy and measures of neuropathic severity in diabetics. It has also been shown that with a return of more normal blood flow, there is a normalization of nerve conduction [16–24].

5. Conclusions

Although VPT measurement is subjective, it is a well-established test to measure sensory loss in DM subjects. This paper presents the first systematic study of the law of mobility to assess the sensitivity on diabetic subjects, comparing the law of mobility of VPT in lower extremities of DM patients.

We observe that the law of mobility does not hold well in DM patients. The VPT data for DM subjects reveals that the law of mobility do not hold good in the foot areas, and all the 25 DM subjects we tested defied the law. The law could well be used to improve the accuracy of the VPT test for diagnosing neuropathy.

REFERENCES


