DYNAMIC POSTUROGRAPHY IN ASSESSMENT OF POLYNEUROPATHIC DISEASE

T. Ledin,* L. M. Ödkvist,* M. Vrethem,† and C. Möller*

Departments of *Oto-Rhino-Laryngology and †Neurology, University Hospital, Linköping, Sweden
Reprint address: T. Ledin, Dept. of ENT, University Hospital, S-581 85 Linköping, Sweden

Abstract — Twenty-eight patients with polyneuropathy aged 49–82 years (mean 67 years) were assessed by dynamic posturography. The patient group was compared to a control group comprising 29 healthy controls aged 70 through 75 years (mean 73 years). The dynamic posturography method comprises a sensory organization part in which the platform and visual surround are either stable or referenced to the patient's sway; furthermore, the eyes are open or closed. In a movement coordination part the platform makes active movements. In the sensory organization part of the dynamic posturography the patient group showed significantly lower equilibrium performance compared to the control group in the test conditions with absent vision, sway-referenced surrounding, and, finally, sway referenced platform and surrounding. In these conditions the influx of somatosensory information is of paramount importance for stable posture. In the movement coordination test, the patient group showed prolonged muscular response latencies in both forward and backward platform perturbations compared to the control group. It is concluded that dynamic posturography is a valuable diagnostic tool in assessment of the dynamic equilibrium performance in patients with polyneuropathy.

Keywords — dynamic posturography; polyneuropathy; equilibrium.

Introduction

Human balance and posture depend on coordinated integration of sensory input from vestibular receptors and the visual system and somatosensory information from extremities, trunk, and neck. Dysfunction in any of these three sensory systems may result in unsteadiness and imbalance.

Polyneuropathy (PN) affects the sensory and motor nerves with variable severity in different patients. The disease is usually more pronounced in the lower extremities, and is most often (but not always) symmetrical. Sometimes the cause for the disease is known, for example, alcoholism, diabetes mellitus, thyroid disease, or vitamin deficiency. However, in most cases the cause is obscure. It is important to adequately estimate the functional handicap of the patient with PN. Clinical scoring might be crude and subject to interinvestigator reliability problems. The value of nerve conduction velocity (NCV) studies in the diagnosis of PN is undisputed (1), and methods of objective measurement of autonomous nerve function have been presented (2–4), but so far there has been no objective method for judging the functional handicap in PN.

Estimation of human balancing ability by tradition has been limited to static testing conditions: that is, the person stands on a stable support surface during the test. In this way the effects of vision may easily be tested, but the role of the somatosensory system is not studied. The static posturography in our laboratory has proven useful in the assessment of solvent-related CNS lesions (5–7) and in unilateral vestibular loss (8).

Recently, a method of studying equilibrium performance under dynamic conditions has been devised (EquiTest, Neurocom Int
Inc, Clackamas, OR, USA) in which the support surface and the visual environment may be moved either actively or in phase with the tested subject's sway. In this way an opportunity is given to study the balance function in situations that are more similar to the disturbances in daily life. Dynamic posturography has been utilized to study balance performance in for example, bilateral vestibular loss (9) and cerebellar–brainstem disturbances (10).

The present study was designed to evaluate the importance of the peripheral somatosensory system and the motor system on equilibrium using dynamic posturography in a group of patients suffering from confirmed PN. Assessment of functional handicap in PN is important in order to follow the course of the disease and also in assessment of treatment results. Using dynamic posturography, the visual influx may be absent or distorted, and the somatosensation from the lower extremities distorted. Furthermore, the muscular activation in response to sudden translations and tiltings of the support surface may be studied. In this way an objective description of the balancing performance under various conditions is obtained.

**Material and Methods**

The patient group comprised 28 subjects (19 males, 9 females) aged 49 to 82 years (mean 67 years) suffering from PN. The diagnoses of PN were previously made by a neurologist due to standard criteria, that is, at least two of the following symptoms or signs were demonstrable:

- Distal bilateral sensory (pain, touch, or proprioception) impairment
- Distal bilateral muscle weakness or atrophy
- Bilateral loss or decrease of tendon reflexes.

Decreased NCVs were found in at least 2 of 4 measurements (sensory NCV in median and sural nerves, motor NCV in median and peroneal nerves) in 24 of 28 patients. Cobalamin, folic acid, and plasma electrophoresis were normal. The duration of PN varied from 2 to 20 years. All except one patient with pure sensory PN were judged to have mixed motor and sensory PN. All patients had symmetrical involvement of the extremities. Three patients had PN due to hypothyroid disease or had elevated thyroxin levels, 2 patients suffered from diabetic PN, and one condition was caused by alcohol abuse. The remaining 22 patients were assessed to have PN without known etiology.

Scholz et al (11) showed high incidences of both peripheral neuropathy and cerebellar ataxia in chronic alcoholics, albeit of different mechanisms. Since only one patient was an abuser of alcohol, the patients were primarily considered to have an idiopathic PN mainly affecting the peripheral nervous system. The clinical investigation and the neurophysiological measurements supported this assumption.

In addition to the dynamic posturography, the patients underwent a thorough neurological examination with scoring of the degree of neurological signs, symptoms, ataxia, and disability. As stated above, all patients were also assessed regarding NCVs in motor (median and peroneal) as well as sensory (median and sural) nerves to detect signs of nerve damage. Furthermore measurement of vibration sense thresholds in feet and hands were performed. These findings will be described in a separate paper (Vrethem et al, unpublished observations).

The control group consisted of 29 healthy subjects (14 males, 15 females) aged 70 through 75 years (mean 73 years), none of whom had any signs of neurological disease.

Dynamic posturography (EquiTest, Neurocom Int Inc) was performed as described by Nashner (12) and Cyr et al (13). In the dynamic posturography, which was performed in the standard premanufactured way, the subject stands on a dual forceplate enclosed by a visual surround. Both the forceplate and the surround can be made to move with the person's anteroposterior (AP) sway or independent of the sway, thus enabling programmed disturbances of the equilibrium. The dual forceplate records the vertical forces between feet and ground as well as horizon-
tctal shear forces, thereby allowing estimation of the position of the swaying body as well as the pattern of sway in terms of hip or ankle strategy.

The investigation is divided into two main sections: sensory organization test (SO) and movement coordination test (MC). The fundamentals of the SO part are thoroughly described by Black et al (14) and those of the MC part by Diener et al (15). The SO part is divided into 6 separate tests (Figure 1), lasting 20 seconds each, with tests 4, 5, and 6 repeated 3 times. SO 1 is a quantified version of Romberg's test. The subject stands with eyes open and the surrounding as well as the ground are stable. SO 2 is equal to SO 1 except that the eyes are closed. In SO 3, performed with eyes open, the visual surround moves in response to the body sway. In test SO 4 the platform is sway-referenced and the surrounding stable. In test SO 5, with eyes closed, the platform is sway-referenced, and in test SO 6 both the platform and the surrounding are sway-referenced. Note that in SO 3 and SO 6 the tested subject might have some orientation information from the surrounding, as it is only moving in the AP direction and not in the lateral direction.

From each test an equilibrium score is computed. The score is 100 for absolutely no sway, decreasing with increasing sway range during the 20 seconds measurement time, and zero in case of 12.5 degrees sway range, or falling. A strategy score, related to the amount of shear force exerted, is computed expressing the degree of ankle or hip movements—the more shear force the more of hip movements. A strategy score of 100 means solely ankle and no hip movements, and zero corresponds to a horizontal shear force of about 110 N. Alignment data, that is, the angle between body and earth vertical, are also calculated during the trial. Initial alignment describes the conditions before the start of each test, and dynamic alignment is the angle during the test.

The MC part is divided into 8 separate tests: small, medium and large backward and forward translation perturbations of the platform, to simulate falling forward and backward, are repeated 3 times each, and furthermore the platform is tilted toes-down and toes-up 5 times each.

From the translation perturbations the force response of each foot is evaluated to yield force symmetry scores between right and

<table>
<thead>
<tr>
<th>VISUAL CONDITION</th>
<th>FIXED</th>
<th>EYES CLOSED</th>
<th>SWAY-REFERENCED</th>
</tr>
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<tr>
<td>SUPPORT CONDITION</td>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>SWAY-REFERENCED</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>6</td>
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</tbody>
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Figure 1. The test conditions in the SO part of the dynamic posturography.
The slope and latency of force recruitment for each foot are also assessed to give estimations of the reaction of each foot separately. The average values of both feet were used in the analysis, as no subject had an asymmetric involvement of the nerves or asymmetric muscle force between the extremities. A strategy score is also in the MC part used to estimate the degree of hip compared with ankle strategies. Finally, the toes-up and toes-down tiltings are evaluated to estimate the adaptation in terms of decreasing energy required to correct the disturbance.

**Statistical Analysis**

Groups were compared using Wilcoxon's 2-tailed rank sum test, as data could not be assumed to be normally distributed. Significance levels below 5% were considered significant.

**Results**

In test condition SO 1 (Romberg's test with eyes open), all subjects remained stable and no significant difference between the groups was found. In condition SO 2 (Romberg's test with closed eyes) a significantly lower equilibrium score \( (P < 0.01) \) was found in the PN group compared to the controls. This was the same in condition SO 3 (sway referenced surrounding, \( P < 0.01 \)). In conditions SO 4 (sway-referenced platform) and SO 5 (eyes closed and sway-referenced platform) no significant differences between groups were found. Finally, in condition SO 6 (sway-referenced platform and surrounding) a significantly lower equilibrium score in the PN group \( (P < 0.05) \) was found. The equilibrium strategy also showed significant differences in conditions SO 2, 3, and 6 \( (P < 0.05, P < 0.01, \text{and } P < 0.05, \text{respectively}) \). For details, see Table 1.

The latencies of the motor responses as evaluated from the MC tests showed significant differences between groups in both forward and backward movements of the platform, with the PN group displaying longer latencies (Table 2).

In the other test parameters of the movement coordination test, for example, adaptation to rotational perturbations of the platform, laterality in the force responses between feet, and strategies for coping with

<table>
<thead>
<tr>
<th>Perturbation type</th>
<th>Polynephropathy</th>
<th>Controls</th>
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</thead>
<tbody>
<tr>
<td>Backward small</td>
<td>217 (38.0)</td>
<td>202 (35.6)</td>
</tr>
<tr>
<td>medium</td>
<td>178 (25.1)</td>
<td>163 (21.0)</td>
</tr>
<tr>
<td>large</td>
<td>169 (36.2)</td>
<td>141 (13.4)</td>
</tr>
<tr>
<td>Forward small</td>
<td>213 (34.1)</td>
<td>192 (15.5)</td>
</tr>
<tr>
<td>medium</td>
<td>188 (56.7)</td>
<td>157 (15.0)</td>
</tr>
<tr>
<td>large</td>
<td>171 (40.6)</td>
<td>142 (12.7)</td>
</tr>
</tbody>
</table>

\* \( P < 0.05 \), \** \( P < 0.01 \). NS = nonsignificant.
linear perturbations of the platform, no significant differences were found between groups.

**Discussion**

Patients suffering from PN were tested with dynamic posturography, a new equilibrium assessment method involving both static and dynamic procedures. It must be remembered, though, that the measurement periods were rather short (20 seconds), thus the influence of decreased muscular strength and endurance, which are common in PN, may not have been studied in their full extent. However, to study these items was not the scope of this investigation.

This study suffers a methodological drawback in that the age distributions of the 2 groups were not identical. It is well known that balance function decreases with increasing age (16). However, as the control group was the older one, the observed differences would likely hold true if the control group were age-matched. Thus, the positive findings are very solid. On the other hand, in tests where no significant differences were found, there might have been differences that were not observed in these conditions.

The results showed worse performance when vision was excluded (SO 2), distorted (SO 3), or when the platform was sway-referenced and vision distorted (SO 6). The patients with PN obviously needed more visual cues to maintain steady equilibrium, which in test conditions SO 2, 3, and 6 were not available. On the other hand, no difference was observed when these subjects were compared to the control group in the conditions in which both the platform and the visual surround were stable (SO 1). Hence, the Romberg test with eyes open appears insensitive in patients with PN. Also when the support surface was sway-referenced (SO 4), there was no difference. In this case the already diminished somatosensory information from the lower extremities was not reliable, thus presenting perhaps only a minor problem for the patients. This explanation also holds true for condition SO 5, where the support surface was sway-referenced and vision was absent. In these conditions, the control group had less contribution from their intact somatosensory system and accordingly the two groups did not differ significantly. This is a plausible explanation as to why the PN patients were not abnormal in conditions SO 4 and SO 5 compared to the control group. The discrepancy of statistically significant effects on equilibrium scores between tests SO 5 and SO 6 stresses the deceiving effect of inaccurate visual information when somatosensory inputs are diminished.

The strategy scores differed between groups in conditions SO 2, 3, and 6 as well. As the strategy score in most cases is dependent on the equilibrium score with low strategy scores accompanying low equilibrium scores, it is difficult to use it as a diagnostic tool for groups of patients without prior knowledge of the equilibrium score distribution. However, a low equilibrium score is not always accompanied by low strategy scores, as some types of equilibrium disturbances are associated with large sway, but have normal strategy scores. But, as the subjects were considered to suffer exclusively from PN, we conclude that the decreased strategy scores are effects of larger sway. This seems logical as the differences in equilibrium scores showing statistically significant results were all accompanied by significantly decreased strategy scores. Due to impaired somatosensory influx, the patient with PN is perhaps exposed to larger equilibrium disturbances before they are detected and corrective motions initiated. Hence, the patient has to use hip strategy to regain balance as the ankle strategy is not sufficient to reestablish equilibrium.

As could be expected, the latencies in the MC test differed between the PN patients and the controls in backward as well as forward perturbations. For the smallest amplitude of backward motion, however, no difference was found. This could be explained by the latter being the first perturbation the patient is exposed to during the investigation, thus eliciting an element of surprise and more variable responses than the others. The latencies
depend on the NCVs in afferent nerves, the processing time in the CNS muscle synergy generators, the NCVs in the efferent nerves, and, finally, the time the muscles require to exert a torque around the ankles to counteract the movement. The decreased NCVs and impaired sensory function in PN is a reasonable explanation for the prolonged latencies observed compared to the controls.

In the statistical evaluation the Wilcoxon rank sum test was used to compare groups. Observing the large standard deviations in the patient group, an illusion of nonsignificance may occur. However, the rank sum tests use ranks, not absolute values, and are less sensitive to skew distributions of data. It is without doubt the method of choice for this type of observations.

It is difficult to make a severity scoring system in PN based on case history, clinical investigation, and neurophysiological measurements; thus, the need for quantitative methods that assess functional performance is obvious. With a sensitive method like dynamic posturography, the equilibrium disturbances in polyneuropathic disease will be detected earlier and with greater sensitivity than with traditional neurological and neurophysiological methods, which do not suffice when the dynamics of the postural system are to be evaluated. Dynamic posturography should help evaluate the functional performance of each patient, thus being a tool for the follow-up, recording the course of the disease and also the effect of training.

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REFERENCES