Dynamic posturography findings in stroke patients

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ABSTRACT
Objectives: To evaluate the role of sensory functions on balance deficits in hemiplegic patients using computerized dynamic posturography.

Setting: Cornell Medical Center at Burke Rehabilitation Hospital, New York.

Subjects: Fifty stroke patients who met the study criteria were selected for this study. Twenty five age-matched subjects were tested and used as a control group.

Methods: Sensory organization was evaluated in quiet standing with standard Equi-Test procedure consisting of six test conditions. Patients were exposed to three consecutive 20-second trials for each condition.

Results: Sensory condition characteristics in stroke patients were significantly different in all six conditions from those of the age-matched normal subjects. Most of the patients studied had great difficulty standing on four out of six conditions. Significant differences were seen in proprioception, visual and vestibular sensory analysis between stroke patients and the age-matched normal group.

Conclusions: The result of this study may be used for monitoring the rehabilitation process by providing objective information to overcome the huge difficulties inherent in the clinical and functional assessment.

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Keywords: Posturography, balance, somatosensory, visual, vestibular.

Hemispheric stroke often causes impairments in upright stance leading to major challenges in the management of hemiplegia. This is due to either one or a combination of loss of strength, joint motion,1,2 abnormal muscle discharge patterns,3,4 or recruitment failure in selected postural muscles.5,6 Adequate postural control is a prerequisite for stabilizing the body in upright positions during voluntary movements and mobility.7,8 Deficits in somatosensory, visual or vestibular inputs could lead to a conflict between the integration of those sensory inputs.9 Precise diagnosis requires quantitative assessments of postural stability. Qualitative observational measures cannot distinguish fine variations in stability or efficacy of various therapies.10,11 Quantitative balance assessments presently can be done by a simple moving platform called dynamic posturography. A commercially system developed by Neurocom called Equi-Test is combining a moving platform and visual stimuli to determine sensitivity to perturbations of the sensory inputs important for balance.12,13 The method of dynamic posturography sensory assessment uses a force plate mounted in a device that can translate horizontally and rotate out of the horizontal plane. The subject is surrounded by specialized visual environments that move in the same direction as the subject to provide unreliable information of body orientation with regard to proprioceptive stimuli.14,15,16 The importance of posturography is the ability to differentiate between the three sensory components, visual, vestibular and proprioceptive that control balance. Among the critical factors in the rehabilitation process for the post stroke hemiplegic patients is the ability of independence in performing the activities of daily living (ADL). Rehabilitation therapy is influenced by many factors, including findings that could be determined by posturography.17

This study was designed to evaluate balance deficits in hemiplegic patients using computerized dynamic posturography and to examine the effect of sensory functions on balance.

Methods

Subjects Stroke patients were screened and selected from Burke Rehabilitation Hospital for the study. Fifty patients met the study criteria and enrolled in the study. Twenty five age-matched...
subjects were tested and used as a control group. The stroke subjects met the following criteria: cerebral vascular accident (CVA), medically stable, resident in an inpatient stroke unit, able to stand unassisted for 20 seconds and able to cooperate with testing. No patient had undergone surgical procedures to correct contractures or muscle imbalance resulting from stroke. Subjects were excluded from the study for any of the following reasons: history of any neurological condition other than stroke; history of injury or trauma to the back or lower extremities or known osteoporosis.

**Dynamic posturography sensory evaluation** Quiet standing was evaluation with a computerized dynamic posturography platform (Equi-Test, NeuroCom International). The protocol, which has been previously described^{18} called Sensory Organization Test (SOT), assesses the three sensory components of balance under a variety of altered visual and support surface conditions. The sensory organization refers not only to visual, vestibular and proprioceptive sensations, but also includes selection of appropriate (accurate) senses by the brain (e.g., ignoring somatosensory information on compliant or slippery surfaces). During the SOT, patients were exposed to three consecutive 20-second trials for each condition. The platform's support surface and visual surround were programmed to sway with the subject (sway referencing), thereby producing misleading tactile-proprioceptive or visual input. The objective was to measure the contribution of individual senses in maintaining equilibrium when other senses were either absent or provided with inaccurate information. The following is a description of the manipulations of sensory input during the six conditions of the SOT (Fig. 1).

1. Eyes open, fixed support surface: all sensory modalities (i.e. vision, tactile-proprioceptive and vestibular) enabled.
2. Eyes closed, fixed support surface: absent visual input.
3. Sway-referenced vision, fixed support surface: visual input inaccurate. This condition requires the patient to ignore the visual stimulus and use proprioception and vestibular information for maintenance of balance.
4. Sway-referenced support surface, normal vision: somatosensory input inaccurate. In this condition, proprioception sensory conflict is created by tilting the platform on which the patient stood by an amount that is equivalent to either anterior or posterior sway. Accurate vision and vestibular information were the primary sensory cues available for activation of appropriate muscle responses to maintain balance.
Dynamic posturography findings ... Al-Zamil

Fig. 2 Somatosensory, visual and vestibular analysis in stroke patients and normal subjects.

Fig. 3 Body sway under test conditions in a man aged 72 years compared with a normal age-matched normal volunteer. The above trace shows the path of the COG as the subject was swaying during each test. Bottom trace represents the base line. Vertical lines represent the degree of COG changes from the initial start.

5. Eyes closed, sway-referenced support surface: absent visual input, inaccurate somatosensory input.
6. Sway-referenced vision and support surface: inaccurate visual and somatosensory inputs. Under conditions 5 and 6, when both visual and proprioceptive information are disrupted, the patient was left primarily with the vestibular information as the accurate sensory input for maintenance of balance.

Sensory analyses were obtained by comparing the different conditions. The somatosensory analyses compared condition 2 to condition 1 equilibrium score. Visual analysis compared condition 4 score with condition 1 score. Vestibular analyses compared condition 5 score with condition 1 score.

For each condition during the test, equilibrium scores were calculated for all trials. Equilibrium scores are based on the maximum excursion of the center of gravity expressed as a percentage of the height-adjusted theoretical limits of stability. Scores range from 0 to 100, with 0 representing a fall (protected by harness), and 100 representing perfect stability. Equilibrium scores for each condition were averaged for three trials.

Test procedure All subjects were fitted with a harness system, which prevented them from falling to the floor by attaching the subject if a fall occurred. The patient’s feet were placed over the marking stripe of the two force plates to ensure proper center of gravity alignment during test procedures. During test procedures, if the patient showed signs of fatigue, the test could be interrupted for a brief period (5 to 10 minutes). A fall was defined as a loss of standing balance, such that assistance from a safety harness system or the operator was required. To ensure reliability, the SOT results were compared with the results obtained from 25 normal subjects used as a control group.

Statistical analysis Comparisons among mean values between stroke patients and age-matched normal subjects were performed using the t-test. Results are shown in Table 1.

Table 1: Values for quiet standing

<table>
<thead>
<tr>
<th>Test conditions</th>
<th>Age-matched control (Mean ± SD)</th>
<th>Stroke patients (Mean ± SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1</td>
<td>93.1 ± 6.5</td>
<td>84.6 ± 12.7</td>
<td>.0009</td>
</tr>
<tr>
<td>Condition 2</td>
<td>91.9 ± 2.1</td>
<td>76.8 ± 22.9</td>
<td>.0011</td>
</tr>
<tr>
<td>Condition 3</td>
<td>91.8 ± 3.5</td>
<td>72.6 ± 24.5</td>
<td>.0013</td>
</tr>
<tr>
<td>Condition 4</td>
<td>77.9 ± 12.9</td>
<td>42.8 ± 31.6</td>
<td>.0001</td>
</tr>
<tr>
<td>Condition 5</td>
<td>48.5 ± 23.3</td>
<td>12.2 ± 21.7</td>
<td>.0001</td>
</tr>
<tr>
<td>Condition 6</td>
<td>47.6 ± 26.5</td>
<td>11.2 ± 20.5</td>
<td>.0001</td>
</tr>
</tbody>
</table>

Patient: Mean ± SD given for 30 stroke patients. Normal: Mean ± SD given for 25 age-matched normal control subjects. Equilibrium scores given are for three trials, averages in each of six conditions of quiet standing.

A score of 100 represents perfect stability and zero represents a fall.
Table 2 - Values of sway strategy (100 means perfect stability) and number of falls in stroke patients.

<table>
<thead>
<tr>
<th>Test conditions</th>
<th>Mean no of falls ± SD</th>
<th>Mean sway reference ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1</td>
<td>0.71 ± 0.3</td>
<td>92.2 ± 5.6</td>
</tr>
<tr>
<td>Condition 2</td>
<td>0.27 ± 0.71</td>
<td>89.9 ± 8.6</td>
</tr>
<tr>
<td>Condition 3</td>
<td>0.33 ± 0.76</td>
<td>88.6 ± 12.9</td>
</tr>
<tr>
<td>Condition 4</td>
<td>1.12 ± 1.3</td>
<td>73.3 ± 15.8</td>
</tr>
<tr>
<td>Condition 5</td>
<td>2.41 ± 1.02</td>
<td>73.3 ± 20.7</td>
</tr>
<tr>
<td>Condition 6</td>
<td>2.46 ± 0.97</td>
<td>74.5 ± 18.9</td>
</tr>
</tbody>
</table>

normal groups were carried out using paired Student’s t-tests. Posturographic results were evaluated by appropriate models of analysis of variance (ANOVA).

Results Posturography studies were completed in the group of 50 patients diagnosed as having a cerebrovascular accident that led to stroke. The 50 patients (22 men, 28 women) had a mean age of 66.9 years (minimum 33, maximum 96). They were assessed within a mean time of 3.5 weeks (minimum 1 week, maximum 8.5 weeks) after sustaining a cerebrovascular accident. The hemiparetic subjects had suffered an infarct of the thromboembolic (number=36 hemorrhagic (number=14) origin in the location of the cortical (number=16), subcortical (number=18) or mixed (number=14) resulting in a hemiparetic syndrome. The mean age of the control subjects was 62.4 (minimum 31, maximum 84). Applying posturography in stroke patients affords information about the central processing of balance control. This means that the whole sensory processing on balance control is observed in posturography results. When applying this evaluation technique in patients, different patterns of posturography result can be found.

Sensory conditions test Neither sex nor type of stroke (infarct or hemorrhage) had a noticeable effect on postural control. Sensory condition characteristics obtained by posturography in stroke patients were significantly different in all six conditions from those of the age-matched normal subjects (Table, 1). Most of the studied patients (38 of 50) had great difficulty standing on conditions 3, 4, 5 and 6 but were otherwise normal. The number of falls during the test were increased when two sensory inputs disrupted or eliminated as in conditions 5 and 6 (Table 2). This abnormal response in conditions 5 and 6 showed a vestibular deficit. The mean composite score of all six different tests was 39.7 ± 17.9 in stroke patients and 70.1 ± 12.4 in age-matched normal population (p<0.005).

Sensory analysis Somatosensory organization characteristics obtained by posturography in stroke patients were significantly different from those of the age-matched control population. Figure 2 shows somatosensory, visual and vestibular sensory analysis in stroke patients and age-matched normal groups. Significant differences were seen in somatosensory (p<0.05), vision (p<0.005) and vestibular (p<0.005) analysis. Somatosensory scores in stroke patients were 10% less than in normal subjects. The most considerable deficit in sensory scores were seen in vestibular analysis (72% less than normal scores).

Sway referenced Total sway during the 20-second period was recorded for the six test conditions. Figure 3 shows an example of sway tracings for the six conditions in a male stroke patient aged 72 years (A) and a normal matched age man (B). The average sway values of stroke patients under conditions 1, 2 and 3 were lower (smaller sway activity) than those under conditions 4, 5 and 6 (Table 2). Weight shift is shared almost equally between the two feet in normal population whereas most patients loaded the unaffected lower extremity more than the affected one.

Discussion Since postural abnormalities associated with age are often confounded with those of stroke, we controlled this problem by comparing stroke patients with age-matched normal control. Our goal was to identify parameters of sensory organization (SOT) applicable for clinical use as a balance assessment and rehabilitation for high-functioning stroke subjects. Our investigation was limited to the study of ambulatory stroke subjects who could understand simple instructions. Stroke subjects requiring the use of an aid or device to stand, may not be an appropriate group to use with the SOT. Sensory organization is highly specific in comparison to the various assessment scales for the evaluation of the sensorimotor status following stroke. The Equi-Test system identifies abnormal somatosensory, visual and vestibular subscores following stroke. The results of the present study revealed findings of sensory inputs on postural control system in stroke patients. The abnormal vestibular contribution on postural control could be attributed to the diffuse vestibular pathways in the brain that may be affected by stroke. The findings that vestibular sense is severely disturbed in hemiplegic patients is in accord with the findings of Wing et al.
Measurement of postural sway in this study, was based on monitoring the variation of the center of pressure of both feet when standing on force platform. The difference of sway in stroke patients may be referred to the different clinical features that are associated with stroke,22,23 cognitive disorder, hemi-inattention and motor, somatosensory and other sensory deficits that may influence postural control. Balance control has been described as representing central ensemble24 of the different sensory inputs, including the somatosensory, visual and vestibular which are difficult to quantify accurately and thus reduce the efficacy of the clinical approach. As a result, the work represented here may be used as tools for monitoring the rehabilitation process by providing objective information to overcome the huge difficulties inherent in the clinical and functional assessment. Further studies are required to determine the usefulness of the dynamic posturography system to predict locomotor outcome during recovery process after stroke.

Conclusion Posturography patterns and sensory analysis do not provide a diagnosis in the sense of defining a patient as having an infarct or hemorrhagic type of stroke, location of the lesion and visual deficit as a result of stroke. These diagnoses were already defined by other data of the examination. However, posturography provides functional data, which furnishes another subdivision of the patients, characterizing their balance in standing. Sensory interaction testing points to various conditions where balance is more likely to be affected. Hence, advice can help the patient in his daily life and appropriate exercises may be suggested to improve balance performance.

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References


