

## Postural Control in Benign Paroxysmal Positional Vertigo Before and After Recovery

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Thirty-two patients affected by idiopathic benign paroxysmal positional vertigo (BPPV) of the posterior semicircular canal were studied before, 3 days and 1 month after a resolutive Semont manoeuvre by means of dynamic posturography. The overall postural control in BPPV patients was shown to be impaired, as demonstrated by the pathological equilibrium scores. Data obtained before treatment showed a specific pattern of vestibular involvement and a pathological composite score. After the liberatory manoeuvre the Sensory Organization Test indicated a significant improvement in the pathological composite and vestibular scores. However, significant differences from controls were still detected 3 days and 1 month after clinical recovery from BPPV. The results clearly show that, in BPPV patients, there is an impairment of the vestibular system, which seems unable to maintain a normal postural balance. This deficit can be particularly detected when dynamic posturography evaluates the vestibular cues. After the liberatory manoeuvre a consistent improvement in the overall postural control has been observed but the residual differences from controls seem to suggest that damage to the otoconial maculae influences postural control, even when there is significant improvement in the clinical signs. *Key words:* dynamic posturography, postural balance, benign paroxysmal positional vertigo, Semont manoeuvre.

### INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is the most common peripheral vestibular end-organ disorder (1). Vertigo is evoked by otoconial debris coming from the utricular macula which abnormally excites the posterior canal receptors.

BPPV, although usually self-limited, is quite disabling as it is clinically characterized by paroxysmal attacks of positional vertigo and nystagmus. Some patients also refer to standing and walking disturbances (2), but if specifically investigated most of them describe a mild ataxia.

This postural instability found in BPPV has been documented by craniocorpography (3), vestibulospinal tests (4), static posturography (5–11) and dynamic posturography (2, 12). An increase in the anteroposterior rather than the mediolateral sways (5, 6, 8), especially during paroxysmal vertigo evoked by the critical head positioning (7), has been detected by means of static posturography. Dynamic posturography, which is able to detect sensory loss or sensory interaction abnormalities, has shown a general impairment of the vestibular system (2, 12).

It has been demonstrated that the Semont manoeuvre significantly relieves the symptoms of BPPV (13), but postural control after this manoeuvre has been investigated only by means of static posturography (8), which showed an improvement in the postural balance.

This research aims at investigating postural control in a group of patients affected by BPPV before, 3 days and 1 month after the liberatory manoeuvre by

means of dynamic posturography, in order to investigate the physiopathological mechanisms and time-course of postural imbalance.

### SUBJECTS AND METHODS

Thirty-two patients, 25 women (mean age 51.6 years) and seven men (mean age 53 years) affected by BPPV were enrolled in the study. All patients underwent a complete clinical neuro-otological examination. The patients' data were compared with gender- and age-matched controls of 32 healthy normals. Paroxysmal positional vertigo occurred in all patients and clinical observation was carried out within 10 days from its onset (mean 4 days). Criteria for diagnosis of BPPV were the presence of positional vertigo and a rotatory, transitory (5–30 sec), brief-latency (1–5 sec), fatiguable nystagmus in the Dix–Hallpike position, which reversed when assuming the upright position.

Patients with a history of symptoms, physical findings or laboratory tests indicating the presence of CNS, ocular motility or middle ear diseases were not included. Electronystagmographic recordings during bithermal stimulation showed an asymmetrical labyrinthine response in seven patients. Only cases with idiopathic BPPV of the posterior semicircular canal (PSC) were enrolled.

The liberatory manoeuvre of Semont was performed as follows. The patient, lying on the pathological side with the head turned 45° up for at least 4 min, was rapidly brought into the contralateral side with the head turned 45° down. The final position

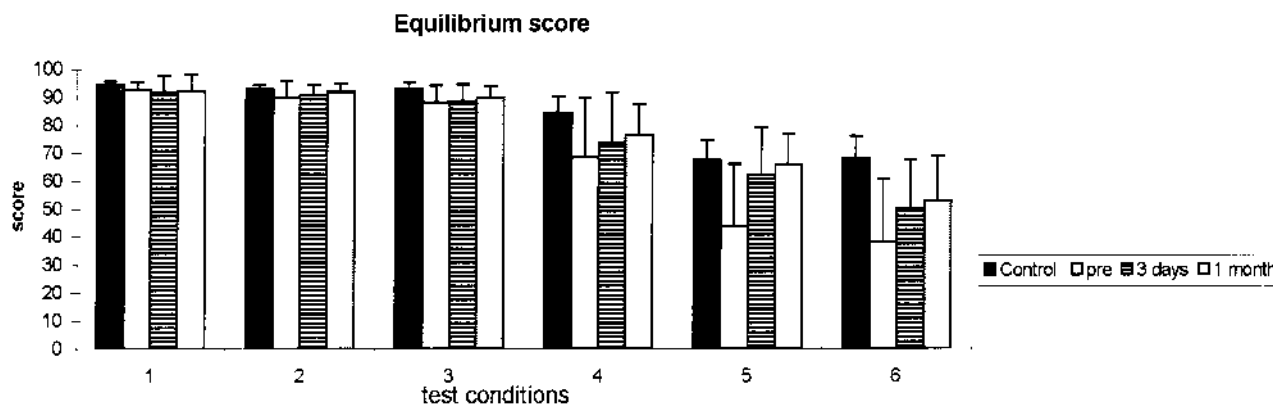


Fig. 1. Equilibrium score in the six different test conditions.

was maintained for 4 min. Evidence of liberatory nystagmus at the end of the manoeuvre, or shortly afterwards, showed that it was successful. All patients were carefully instructed to avoid any movement or position that could cause recurrence of the disease, i.e. not to bend over, look up or down with their head or lie down on the affected side.

Dynamic posturography was performed before, 3 days and 1 month after the liberatory manoeuvre. The outcome was recorded as follows: those with no further positional vertigo and negative Dix-Hallpike manoeuvre were enrolled into the study ( $n = 30$ ), whereas those who still showed the paroxysmal positioning nystagmus ( $n = 2$ ) were considered a failure and the Semont manoeuvre was attempted once more, with a complete response.

In order to avoid possible interference due to the diagnostic manoeuvre, dynamic posturography (Equitest, Neurocom International, Clackamas, OR, USA) was performed at least 1 h after the Dix-Hallpike manoeuvre with the subject standing on a dual forceplate enclosed by a visual surrounding.

The dual forceplate records the vertical forces between the feet and ground, as well as horizontal shear forces, thereby allowing estimation of the position of the swaying body. The Sensory Organization Test (SOT) consists of six different conditions, each lasting for 20 sec, which were repeated three times so as to obtain more stable values. The conditions were as follows (Fig. 1).

1. The eyes were open, and the platform surface and visual surroundings fixed.
2. As condition 1, but the subject's eyes were closed.
3. The platform was fixed while the visual surroundings kept moving around an axis collinear with the patient's ankle joint, in direct proportion to the anteroposterior sway of the patient's

centre of gravity. In this way the patient could not perceive changes in the body sway orientation with respect to the visual surrounding (14).

4. The visual surrounding was fixed, the eyes were open and the platform was kept moving in direct proportion to the patient's sway so that changes in the patient's orientation with respect to the platform were cancelled.
5. The visual surrounding was fixed, the eyes were closed and the platform was kept moving as in condition 4.
6. The eyes were open, and the platform and visual surrounding were rotated proportionally to the anteroposterior body sway.

The composite equilibrium score (ES) indicating the range of sway angle with respect to the earth vertical was computed for each condition. The following formula was used:

$$ES = 12.5^\circ - (\theta_{\max} - \theta_{\min}) \times 100/12.5^\circ,$$

where  $\theta$  is the angle between a line extending vertically from the centre of the foot support and a line extending from the centre of the foot support through the centre of gravity.

Sensory analysis calculating the relationships among the equilibrium scores in the six conditions identified the sensory dysfunction and individual preference for different inputs: somatosensory (test condition 2/1), visual (4/1), vestibular (5/1) and vision preference (3 + 6/2 + 5).

#### Statistical analysis

All results are expressed as means  $\pm$  SD. Analysis of variance (ANOVA) with repeated measures was performed and differences  $p < 0.05$  were considered significant. The Scheffé test was used to make paired comparison tests among the control and BPPV groups.

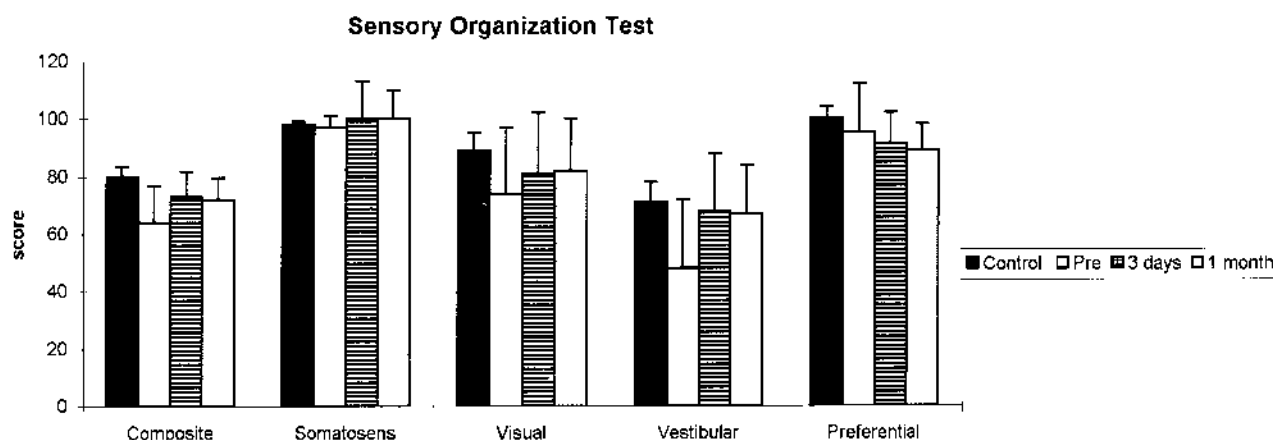


Fig. 2. Sensory Organization Test scores in the different groups.

## RESULTS

The pretreatment group patients (Pre), compared with normals (N), showed a normal performance in the less challenging condition (1), while the equilibrium score worsened significantly in the more difficult conditions (2–6) (Fig. 1, Table I).

In the sensory analysis the composite, vestibular, visual and preferential scores of the pretreatment group were significantly reduced in comparison with normals (Fig. 2, Table II).

At least one fall was registered during the SOT (test condition 6) in eight patients before the liberatory manoeuvre.

Equilibrium scores of the patients 3 days and 1 month after treatment were significantly lower in conditions 2–6 compared with controls, but significantly higher compared with those observed before treatment (Fig. 1, Table I).

After the liberatory manoeuvre no significant differences were found among the scores obtained 3 days and 1 month after treatment. Even though composite, vestibular, visual and preferential scores increased, they never reached the control values (Fig. 2, Table II).

No fall were registered in any patient after treatment.

## DISCUSSION

As far as we know this is the first study to investigate, by means of dynamic posturography, the outcome of postural balance in patients affected by BPPV after a liberatory manoeuvre.

Patients affected by BPPV (pretreated group) showed a consistent impairment of postural control, as their equilibrium score in conditions 2–6 was significantly reduced in comparison with controls. Our data are not in close agreement with those

obtained by Black et al. (12), who observed a reduction in postural stability in BPPV patients in conditions 3, 4 and 6. On the basis of these results the authors attributed the reduction of postural balance to the inaccuracy of visual inputs interfering with the stabilization achieved by both vestibular and somatosensory cues. In contrast, our data clearly outlined an impairment of the vestibular system which seems unable to maintain the postural balance in conditions 5 and 6, where the postural control relies mostly on vestibular cues. This was confirmed by the sensory analysis, which showed a prominent reduction in the vestibular contribution to postural stabilization. A possible explanation for the differences between our results and those obtained by Black et al. (12) is the exclusion in our series of vascular and post-traumatic cases, in which pathways other than the vestibular ones can be involved.

The impairment of vestibular control in the maintenance of postural balance can be explained by taking into account the hypotheses that have been put forward on the pathophysiology of BPPV. Two mechanisms are most often quoted: cupulolithiasis and canalolithiasis (15). In cupulolithiasis the otocorial layer of the utricle is partly detached and becomes fixed to the cupula of the PSC. In canalolithiasis a clot with a density higher than the endolymph floats freely in the PSC. In both cases dynamic activation of the posterior canal receptors is altered as a result. As it has been recognized that the vertical semicircular canals contribute to the control of postural sway (14, 16), it is reasonable that the modification of canal dynamics ensuing from the presence of a clot in the PSC (and/or from modification of the inertial moment of the cupula) may affect the discharge of the vestibular afferents. The lack of correct vestibular information from one side may cause abnormal vestibulospinal output.

Table I. *Equilibrium scores in the six different test conditions*

Test conditions	Control	Pre	3 days	1 month	ANOVA	Control vs pre	Control vs 3 days	Control vs 1 month	Pre vs 3 days	Pre vs 1 month	3 days vs 1 month
1	94.4 ± 1.2	92.6 ± 2.9	91.9 ± 5.9	92.1 ± 6.0	$p = 0.89$	0.7	0.8	0.6	0.6	0.7	0.8
2	92.8 ± 1.5	90.0 ± 5.9	90.9 ± 3.5	91.9 ± 3.0	$p = 0.04$	0.03	0.04	0.03	0.04	0.05	0.6
3	92.9 ± 2.2	88.0 ± 6.1	88.5 ± 6.1	89.7 ± 4.0	$p < 0.01$	0.009	0.01	0.01	0.01	0.01	0.8
4	84.3 ± 5.9	68.5 ± 21.1	73.6 ± 18.0	76.5 ± 11.0	$p < 0.001$	0.0007	0.001	0.003	0.001	0.001	0.09
5	67.5 ± 7.0	43.7 ± 22.2	62.1 ± 17.1	65.8 ± 11.0	$p < 0.001$	0.0005	0.001	0.001	0.001	0.001	0.09
6	68.0 ± 7.9	37.9 ± 22.8	49.8 ± 17.9	52.8 ± 16.0	$p < 0.001$	0.0004	0.0006	0.005	0.001	0.001	0.08

Values are shown as mean ± SD and ANOVA with repeated measures.

Table II. *Sensory Organization Test scores in the different group*

	Control	Pre	3 days	1 month	ANOVA	Control vs pre	Control vs 3 days	Control vs 1 month	Pre vs 3 days	Pre vs 1 month	3 days vs 1 month
Composite	80 ± 3.5	64 ± 12.7	73 ± 8.8	72 ± 7.6	$p < 0.001$	0.0005	0.001	0.001	0.0001	0.0001	0.7
Somatosensory	98 ± 1.0	97 ± 40	100 ± 13	100 ± 10	$p = 0.443$	0.07	0.62	0.7	0.5	0.5	0.64
Visual	89 ± 6.0	74 ± 23	81 ± 21	82 ± 18	$p < 0.01$	0.002	0.007	0.005	0.003	0.005	0.43
Vestibular	71 ± 7.0	48 ± 24	68 ± 20	67 ± 17	$p < 0.001$	0.0001	0.001	0.001	0.0001	0.0001	0.34
Preferential	100 ± 4.0	95 ± 17	91 ± 11	89 ± 9.0	$p < 0.02$	0.002	0.001	0.001	0.004	0.006	0.2

Values are shown as mean ± SD and ANOVA with repeated measures.

The low visual score obtained by performing SOT analysis indicates the poor utilization of visual cues to achieve postural balance in BPPV patients and thus an increased body sway in response to visual surrounding motion. This result can be explained by a decrease in the vestibular effectiveness in suppressing postural sway during visual stimulation, as demonstrated by Peterka & Benolken in vestibularly impaired patients (17).

After the liberatory manoeuvre a consistent improvement in the overall postural control has been observed. The equilibrium score increased in conditions 2–6, although remaining significantly lower than the corresponding control values. Sensory analysis showed a significant recovery of both the vestibular and visual components. These results are in agreement with those obtained by Boniver (8), who showed an improvement in postural balance in BPPV patients after the liberatory manoeuvre, by means of static posturography. However, in contrast with our data, they observed a complete recovery of postural balance. This can be explained by considering the differences in the experimental set-up (static or dynamic posturography).

The recovery of vestibular control on postural balance after the Semont manoeuvre is strictly related to the mechanisms underlying the pathogenesis of BPPV. According to the canalolithiasis hypothesis, one can speculate that the Semont manoeuvre can act by removing a high-density floating clot from the PSC. The improvement of postural control after the liberatory manoeuvre is paralleled by the relief from positional vertigo, but patients still complain of a mild unsteadiness. Partial recovery, even after 1 month, could be due to unequal loads of the utricular macula beds resulting from detachment of the clot floating in the PSC from the otoconial maculae. In this case the Semont manoeuvre may restore the canalar function, leaving the previously impaired otolithic function unaltered. Pure otolithic damage observed in post-traumatic vertigo without BPPV (18) can be clinically evident only as an imbalance in gait, exactly as observed in our patients after an effective liberatory manoeuvre. Such otoconial maculae damage probably takes longer to recover (19, 20). In conclusion, dynamic posturography is able to detect the postural imbalance due to VPPB and to monitor the long-standing unsteadiness which is probably due to otolithic damage.

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