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ORIGINAL REPORT

ASSESSMENT OF POSTURAL INSTABILITY IN PATIENTS WITH TRAUMATIC BRAIN INJURY UPON ENROLMENT IN A VOCATIONAL ADJUSTMENT PROGRAMME

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Objective: **To assess postural instability in patients with traumatic brain injury upon enrolment to vocational adjustment.**

Design: **A cross-sectional study.**

Patients and methods: **Sixty-eight patients at the time of admission to a vocational adjustment programme and 52 healthy age-matched controls were evaluated. Complaints of dizziness, or balance impairment and data from a clinical examination were recorded. Postural characteristics during quiet upright standing were assessed using a static posturographic platform.**

Results: **Twenty-six patients complained of dizziness or instability and 36 had evidence of neurological impairment. Centre of pressure displacement and area were significantly increased in the traumatic brain injury group as a whole, compared with controls, even among 23 patients who had no complaint or clinical abnormality.**

Conclusion: **In spite of a high variability in time since injury, significant posturographic abnormalities were found in patients with traumatic brain injury, including those who had no complaints or evidence of neurological impairment. Posturography may help in understanding how a traumatic brain injury impairs the human balance, and may provide helpful information for patients participating in vocational adjustment programmes, especially when jobs require a long standing posture or balance.**

Key words: balance impairment, posturography, traumatic brain injury, return to work.

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INTRODUCTION

Postural instability and balance impairment are common complaints among patients with traumatic brain injury (TBI) and an incidence as high as 30% has been reported (1–4). They represent a source of discomfort and unpleasant feelings and, in severe cases, place real restrictions on autonomy and social life.

In mild brain injury, complaints of balance impairment, vertigo and feelings of dizziness are frequent (5). Their legitimacy has been questioned in the past, especially when there was no evidence of neurological impairment at clinical examination, and they were thought to be related to psychological causes and post-concussional syndrome. Later on, studies using standardized data or force-platform recordings provided evidence of slight dysfunction of the complex and multimodal integration systems involved in standing balance (2, 3, 6, 7).

In severe TBI, brain imaging, especially magnetic resonance imaging (MRI), may show focal brain damage in motor and cerebellar areas or pathways, and/or diffuse axonal injury (8). Often patients do not complain, so the relationship between complaint of dizziness and evidence of balance impairment remains a matter of debate (8–10). Force-platform studies provide more precise information. When standing quiet on a posturographic platform, persons with TBI tend to sway more in the antero-posterior and lateral directions, and to be slower in weight-shifting, than controls (6, 8, 9, 11). They may have difficulties in using vestibular and somatosensory information accurately, as suggested by evidence of impaired caloric and optokinetic assessment (6, 9). They may also have increased latency and asymmetrical stance patterns in response to unexpected linear perturbations (10). However, these findings were all made relatively early after injury, essentially during the rehabilitation phases.

Wade et al. (11) reported significant improvement in balance during a relatively short period of specific rehabilitation. Recovery seems to be greater in patients under 50 years of age and after less severe TBI. However, the relationship between severity of balance impairment and severity of TBI is far from clear. Greenwald et al. (12) found that early after TBI, the severity of sitting and standing balance deficits was related to the usual indicators of TBI severity, including the Glasgow Coma Score (GCS). In other studies, unsupported sitting imbalance was significantly correlated to length of stay in rehabilitation units and functional status at discharge (13, 14).

Although some data are available on the early phases of recovery, little is known about the impact of balance impair-

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ment on the ability to return to work, so it is difficult to know whether assessment and balance training should be taken into account at the moment of vocational adjustment.

The present study was undertaken to provide further information on: (*i*) the type and severity of balance impairment that may be observed in patients with TBI upon admission to vocational adjustment; (*ii*) the relationships between complaints, clinical findings and posturographic parameters; and (*iii*) the influence of balance impairment on autonomy in daily living and return to work.

PATIENTS AND METHODS

Patients

UEROS (Unité d'Evaluation, Réentrainement et Orientation Sociale et professionnelle) is a government-funded programme in France for improving community re-entry and vocational adjustment after a brain lesion, whether of vascular or (more frequently) traumatic origin. On average 120 patients are examined every year by the medical commission of the programme in the Bordeaux area (named UEROS Aquitaine network), and 50–60 are selected to enter the programme.

From November 1998 to December 2000, all patients with TBI entering the programme were consecutively enrolled after providing them with information and obtaining their consent, whether they complained of dizziness and suffered from balance impairment or not. Exclusion criteria were: presence of neurological or orthopaedic impairment prohibiting stance without support; severe reduction of visual acuity; and diplopia and evidence of peripheral vestibular impairment at clinical examination (see below). A total of 73 patients with TBI were consecutively considered for inclusion. Five were excluded because of neurological impairment prohibiting stance. The mean time from injury at the time of admission to the programme was large: 55.2 months (standard deviation (SD) 55.3) (median 35 months; range 8–290 months). Indeed, we studied a convenience consecutive sample of patients, and not an experimental prospective one. The sample gets its homogeneity from the fact that all these patients reached the functional status requested for vocational adjustment, and not from time since injury.

Table I. *Demographic, clinical and psychometric data of the patients with traumatic brain injury in sample (n = 68).*

Mean age, years (SD)	33.2 (9)
Gender, men /women (*n*)	55/13
Time since injury (months)	
mean (SD)	55.2 (55.3)
range	8–290
Glasgow Coma Score	
mean (SD)	6.6 (3.5)
< 8	60
≥ 8	8
Post-traumatic amnesia, (*n*)	
> 24 hours	67
> 1 month	57
Psychometric test, mean (SD)	
Wechsler Memory Scale	
Verbal IQ	94.9 (18.7)
Visual IQ	99.1 (13.2)
Wechsler Adult Intelligence Scale	
Verbal IQ	86.7 (13.3)
Performance IQ	87.1 (12.9)
Raven's Progressive Matrix	57.8 (27.7)

SD: standard deviation.

Table I provides demographic and psychometric data on the remaining 68 patients. All but one suffered a severe TBI, as defined by a GCS below 8 on admission and post-traumatic amnesia lasting over 24 hours. Initial brain imaging (MRI or computerized tomography (CT) scan) was available in 58 cases. Focal or diffuse lesions were noted in 20 and 18 cases, respectively. Both types of lesions were associated in 20 patients.

Fifty-two healthy (25 men and 27 women; mean age 31.7 (SD 7.8 years)) age-matched volunteers (hospital employees) were assessed with the same method as patients with TBI (see below). None complained of dizziness or balance impairment.

In 2003, i.e. 3–5 years after initial assessment, we had the opportunity to re-examine 51 patients in the present study. We were unable to re-contact 18 patients and 2 refused to participate. Data on the 31 others were obtained by telephone interview.

We used the European Brain Injury Society (EBIS) document to assess patients with TBI (15). Data were recorded concerning loss of autonomy for physical or cognitive reasons, return to work, sport and leisure activities, and satisfaction with life (3-point scale).

Methods

Clinical data included an enquiry on complaints of dizziness or balance impairment and a neurological clinical examination recording motor and sensitivity status, ataxia, movement disorder, nystagmus, diplopia, Romberg sign and lower limb range of motion.

Psychotropic treatments that might have disturbed posture regulation were recorded.

Cognitive status was documented by the Wechsler Memory Scale (WMS), the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and Raven's Progressive Matrices (PM 38) (16–18). Assessment of injury severity included the GCS on admission and duration of post-traumatic amnesia. Abnormality on initial brain MRI or CT scan were recorded retrospectively and classified as absent, presence of focal damage, diffuse, or mixed brain damage.

Postural data were assessed using a posturographic platform (Satel®, Blagnac, France). Three vertical forces were recorded (after a familiarization session) at 40 Hz during 2 conditions: static with open eyes, then static with closed eyes. During recording, patients were barefoot with the feet aligned according the referential marked on the platform, as proposed by the manufacturer's guideline (Fig. 1). The subjects

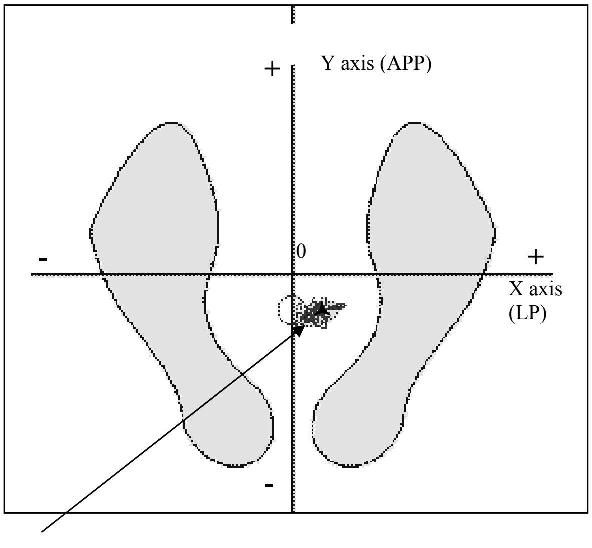

Fig. 1. Mean centre of pressure (CoP) posistion defined by lateral co-ordinate of the CoP position in mm (LP) (+ right deviation; – left deviation) and anteroposterior co-ordinate of the CoP position in mm (APP) (+ forward deviation; – backward deviation)

were instructed to maintain a 2-legged upright standing position for 51 sec (in each condition), with their arms at their sides and, when their eyes were open, to gaze fixedly at a picture. Assessments were performed with a 2 min rest in between.

Displacement of the centre of pressure (CoP) was recorded in a frontal and a sagittal plane, i.e. along the X-axis and Y-axis directions, respectively. The mean value of the CoP position was defined by 2 coordinates: Lateral Position (LP in mm) described the mean position on the X-axis and Antero-Posterior Position (APP in mm) described the mean position on the Y-axis. Indeed, LP and APP are just coordinates and not independent values which represent the means of lateral or antero-posterior sway. A negative (–) or positive (+) sign was assigned to the value of the CoP position when the deviation was observed in a backward or a forward direction, respectively, along the Y-axis. Deviations to the left or right along the X-axis were assigned the (–) or (+) signs, respectively. Then, the total CoP displacement in mm (representing the total length covered by the CoP during the test) and the CoP area in mm^2 (a 95% confidence ellipse encompassing 95% of the points on the CoP trajectory) were computed from the vertical forces and analysed with Satel® software. All recordings were performed in the same standardized environment, in a quiet, well-lit room.

Statistics

Statistical analysis was performed with an SPSS programme. Non-parametrical methods (Mann-Whitney test, Kruskall-Wallis test) were used for comparisons between independent quantitative data (all posturographic parameters), at a significance level $p < 0.05$. The Spearman's rank test was used to study correlations between clinical, psychometric, follow-up data and posturographic parameters. Non parametrical tests were used because data did not follow a normal distribution, and some groups were too small to use parametrical tests.

A one-way ANOVA was performed to look at the influence of time since injury on posturographic parameters. χ^2 test was used to check the influence of gender.

RESULTS

Clinical data

Twenty-six patients, i.e. more than one-third of the sample, complained of dizziness or balance impairment. The clinical examination was found impaired in 17 of these patients, and normal in the 9 others. Among patients who did not complain, the clinical examination was found impaired in 19 cases, and normal in 23 cases. In 36 patients, the clinical examination found evidence of neurological impairment, including 15 patients with a cerebellar syndrome in isolation and 3 with a cerebellar syndrome associated with hemiparesis. Eleven patients suffered from slight to mild hemiplegia (right side in 10 cases) and 7 from sensory loss. Daily use of psychotropic drugs (i.e. antidepressant, neuroleptic and/or hypnotic drugs) was observed in 20 subjects.

Posturographic data (Table II)

In the 68 patients with TBI included in the study, the mean position of the CoP did not significantly differ from the controls, as evidenced by APP and LP values, for both open and closed eyes. But CoP displacement and area were significantly increased with regard to controls (Table II). However, the variation ranges were wide, demonstrating large individual variability inside the patient group.

Table II. *Posturographic data on the patients with traumatic brain injury (TBI) and the controls. Values are given in mean (SD).*

	Patients with TBI ($n = 68$)	Controls ($n = 52$)
Lateral position (mm)		
Open eyes	1.46 (12.10)	0.90 (5.49)
Closed eyes	3.26 (19.80)	0.17 (6.72)
Antero-posterior position (mm)		
Open eyes	–40.48 (14.83)	–38.13 (11.9)
Closed eyes	–37.18 (18.56)	–31.13 (34.55)
Centre of pressure area		
Open eyes	306.68 (360.7)*	119.79 (74.72)
Closed eyes	693.11 (801.62)*	208.95 (106.41)
Centre of pressure displacement		
Open eyes	492.72 (237.05)*	317.13 (79.65)
Closed eyes	850.31 (407.03)*	524.41 (176.31)

*$p < 0.001$.
SD: standard deviation.

Relationships between posturographic parameters and independent variables

No significant correlation was found between any posturographic parameter and age. No influence of gender, scores on cognitive tests, brain MRI or CT scan abnormality, or psychotropic treatment on posturographic parameters was observed. With regard to injury severity, the GCS was correlated with CoP area in the open eyes condition (Rho = –0.31, $p < 0.05$), but there was no significant statistical relationship between posturographic parameters and duration of post-traumatic amnesia. The influence of visual deprivation was strong, with the values of CoP area and CoP displacement significantly increased in the closed eyes condition ($p < 0.001$ for both parameters). As regard to time since injury, 6 patients were examined over 120 months after their injury, because they were injured in their childhood or their adolescence, and accounted for the large range of variance of time since injury. Their posturographic data did not differ from the whole sample of patients. We observed no influence of time between injury and assessment on posturographic data, excepted for the CoP area with open eyes (F = 8.09; $p < 0.001$).

Relationships between complaint and posturographic parameters (Table III)

No significant difference was found between posturographic parameters of patients with or without complaints.

When the patients with or without complaints were compared together to the control group, a significant increase ($p <0.001$) was found for CoP area and displacement, whatever the conditions (open or closed eyes). Concerning age, gender, GCS score and time since injury, no statistical difference was found between patients with or without complaints.

Relationships between neurological impairment and posturographic parameters (Table IV)

Patients with an impaired clinical neurological examination (except those with a sensory impairment in isolation) differed

Table III. *Posturographic mean scores (SD) in patients with or without complaint and control subjects.*

	CoP area		CoP displacement	
	Open eyes	Closed eyes	Open eyes	Closed eyes
Complaint				
Dizziness ($n = 7$)	356 (497.3)	647.4 (893.6)	479.5 (406.4)	823.3 (548.9)
Balance impairment ($n = 19$)	431.2 (546.8)	1061.7 (1261)	618.9 (289.4)	1020.9 (490.3)
Together ($n = 26$)	410.9 (525.2)	945.7 (1167)	581.3 (322.3)	965.5 (503.7)
Absence of complaint ($n = 42$)	242.1 (182.3) NS	542.7 (418.4) NS	437.8 (142.7) NS	781.7 (324.3) NS
Control subjects ($n = 52$)	119.7 (74.72)*†	208.9 (106.4)*†	317.1 (79.6)*†	524.4 (176.3)*†

*$p < 0.001$: comparisons between patients with complaint (as a whole) and control subjects.

†$p < 0.001$: comparisons between patients without complaint and control subjects.

CoP: centre of pressure; SD: standard deviation; NS: no significant difference between patients with complaint and those without.

significantly from those without neurological impairment, with an increase in CoP area and displacement in both open and closed eyes conditions. As in the control group, a strong effect of visual deprivation was observed on both CoP area and displacement ($p < 0.001$ for both parameters).

When the 32 patients who had no evidence of neurological impairment at clinical examination were compared with the control group (Table IV), CoP area and displacement in both conditions (open or closed eyes) were found significantly increased and the difference between open eyes or closed eyes conditions, for CoP area and CoP displacement, was significantly more important in the patient group ($p = 0.03$ for both parameters). Only 9 of them complained of dizziness or instability, i.e. posturographic parameters were found impaired in 23 patients who had no complaint or abnormality at clinical examination.

Relationships between posturographic parameters, outcome and return to work

Three to 5 years after their participation in the UEROS programme, only 15 patients out of 31 were fully independent in daily living and 11 were working (including 4 in sheltered workshops) (Table V). No statistical relationship was found between posturographic parameters and follow-up data.

DISCUSSION

One-third of patients with severe TBI enrolled consecutively to vocational adjustment still complained of vertigo, dizziness or balance instability. Similar rates were reported by our colleagues Masson et al. (4) in an epidemiological sample of patients assessed 5 years after their injury, and by other authors (1–3). Moreover, the complaint may not fully mirror the degree of impairment, as posturographic parameters were found impaired in the majority of our patients, including those who expressed no complaint. Fortunately, the impact of these impairments on daily living does not seem too severe, with only 3 patients needing help for physical reason.

With regard to posturographic results, mean APP and LP of CoP were not significantly different with regard to controls. The large SD observed for posturographic variables may be related to the great diversity among the subjects with regard to the pathophysiological process involved in postural instability, and to the variability of the compensatory process. Using a dynamic procedure, Newton suggested that instability may be related to a combination of long latency of onset of the balance response, coupled with asymmetrical stance patterns during recovery from an unexpected linear perturbation (10). Comparing data from this kind of protocol with CoP area and displacement in a static standing balance condition would be very interesting.

Table IV. *Posturographic mean scores (SD) in patients with or without evidence of neurological impairment and control subjects.*

	CoP area		CoP displacement	
	Open eyes	Closed eyes	Open eyes	Closed eyes
Neurological impairment[1]				
Cerebellar syndrome ($n = 15$)	329.3 (207.8)*	735.7 (466)*	628.7 (311.7)**	994.8 (386.4)**
Hemiparesis ($n = 11$)	676 (744)*	1397.6 (1611.8)*	667 (276.9)**	1191.6(602.8)*
Sensory impairment ($n = 7$)	182.95 (96.1)NS	491.5 (249.3) NS	417 (82.2) NS	687.8 (121.2) NS
Together ($n = 33$)	421.8 (487.6)**	923.3 (1051.9)*	602.1 (279.6)**	1005.2(470.3)**
Absence of clinical impairment ($n = 32$)	199.2 (129.7)	510.7 (437.4)	389.7 (130.3)	720.6 (283.1)
Control subjects ($n = 52$)	119.7 (74.72)††	208.9 (106.4)††	317.1 (79.6)††	524.4 (176.3)††

[1] Except for the 3 patients with associated symptoms.

NS: no significant difference

*$p < 0.05$ and **$p < 0.01$ for comparisons between patients with or without neurological impairment.

††$p < 0.01$ for comparisons between patients without neurological impairment and control subjects.

CoP: centre of pressure; SD: standard deviation.

Table V. *Data at follow-up. Patients with traumatic brain injury (n = 31).*

Mean age, years (SD)	28.4 (7.7)
Gender, men/women (*n*)	24/7
Clinical examination, *n* (%)	
Normal	12 (38.7)
Hemiparesis	5 (16.1)
Cerebellar syndrome	11 (35.4)
Sensory impairment	3 (9.7)
Independence in daily living, *n* (%)	
Independent	15 (48.4)
Dependent for physical reason	3 (9.7)
Dependent for cognitive reason	13 (41.9)
Work status, *n* (%)	
Full-time working	2 (6.5)
Part-time working	5 (16.1)
Sheltered working	4 (12.9)
Student, formation	2 (6.5)
Unemployed	12 (38.7)
Charity work	4 (12.9)
Invalid	2 (6.5)
Sport playing, *n* (%)	
Like before	4 (12.9)
New sport	3 (9.7)
None	24 (77.4)
Satisfaction with life (verbal scale), *n* (%)	
Satisfied	6 (19.4)
Rather satisfied	13 (41.9)
Dissatisfied	12 (38.7)

SD: standard deviation.

Indeed, balance is a complex multifactorial process that simultaneously calls upon information from the vestibular, kinesthetic and visual systems, together with cortical representations of posture. Non-pyramidal motor pathways and cerebellar outputs are involved in the fast and permanent adaptive motor and postural responses. As a diffuse source of axonal damage and focal brain lesions, TBI may impair nearly all the components of the balance process. From a clinical point of view, we found correlations between clinical evidence of pyramidal and cerebellar impairment and posturographic parameters, as expected. We did not take into account the role of vestibular inputs, as evidence of peripheral vestibular impairment at clinical examination was an exclusion criterion. A strong effect of visual deprivation was observed in patients and controls on some posturographic parameters we studied. This key role of vision on balance regulation in patients with TBI has been highlighted by others (8, 9). In comparison, the impact of proprioceptive and sensory impairment appears low, at least in our study.

A limitation of this study is that we took into account only data from the current clinical examination. More reliable and sensitive results would probably have been provided by a standardized assessment procedure, such as the Berg Balance Scale (13) or by looking at more dynamic parameters, such as gait velocity (11), pointing or reacting at unexpected linear perturbation (10). Although cerebellar ataxia is classically thought to be insensitive to visual deprivation, we observed the same effect of eye closing in this group as in others. Whether posturographic data provide more information than the clinical examination in patients with TBI remains to be established. The question is of importance since significant correlations exist between clinical impairment and posturographic parameters, and the issue of whether such expensive platforms are worthwhile should be raised. This seems to be the case, however, since posturography provides global, integrated information about balance and how it changes from one situation to another, whereas the clinical examination provides only isolated information component by component and fails to document how they interact with each other and to capture functional and/or fast or slight changes in postural control. Posturography, and especially integrative parameters, such as CoP area and displacement, are more functional and closer to the neurophysiology of balance regulation than the clinical examination. This is probably why posturographic parameters were found to be impaired in 32 patients who had no evidence of balance or postural impairment at clinical examination (a result that did not seem to be false positives since normal subjects differed significantly from these 32 patients). As far as return to work is concerned, posturographic data are probably more useful in patients with normal results on a clinical examination than in those who are obviously impaired.

Patients who complained of dizziness and instability were performed in an intermediate position between patients with and those without clinical evidence of postural impairment. On one hand, this confirms that patients with severe TBI who complain of vertigo and instability do have a slight organic balance impairment and not only psychological problems; on the other, absence of complaint does not mean absence of impairment, so even patients without any complaint might be referred for posturometry whenever they are subjected to dangerous or unstable work postures or tasks. This may seem self-evident, yet clinicians often refer for posturographic recording only those patients with evidence or are complaining of impaired balance.

Investigating correlations between clinical and posturographic data on the one hand and independent variables and outcome data on the other proved inconclusive. We failed to reproduce the results of Greenwald et al. (12) and Black et al. (14) who found a significant relationship between postural instability and age. We were unable to assess the influence of current indicators of injury severity, such as the GCS, or post-trauma amnesia duration in satisfactory conditions, because our sample included only severely injured patients, with the exception of one. Apart from the study by Wober et al. (8), in which deep parenchymal lesions demonstrated by MRI were shown to be indicators of postural imbalance, the literature provides little evidence of any correlation between brain imaging and posturographic data, even in the large study of Greenwald et al. (12) that included 908 patients. Our study does not provide any further insights into this issue, so more sophisticated dynamic brain imaging techniques will likely be necessary to elucidate the question.

Although sitting balance and, to a lesser degree, standing balance have been shown to be powerful predictors of functional status during the acute recovery phase (13, 14), our follow-up data failed to reveal any relationship between posturographic parameters, autonomy in daily living and return to work. Indeed, cognitive and behavioural impairments play a greater role in vocational and social adjustment than postural instability: among the 16 patients who need help in daily living, only in 3 cases was it required for physical reasons but in 13 for cognitive reasons. Therefore, we do not recommend systematic posturographic recording in every vocational adjustment programme. However, posturography might be very useful whenever the safety of individuals is involved or for jobs requiring a long-standing posture or balance, even when the subject does not actually complain of any instability and the clinical examination is normal.

In conclusion, postural instability and balance impairment are far more frequent in patients with severe TBI upon enrolment to vocational adjustment programmes than is generally thought. Their frequency is probably under-estimated because their impact on daily living is low in comparison with cognitive and behavioural impairment. Posturography may help in understanding how a TBI may impair the complex and multifactorial process of human balance. It may also provide helpful information in assessing patients participating in vocational adjustment programmes whenever the safety of individuals is involved or when jobs require a long-standing posture or balance.

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