ORIGINAL ARTICLE

Posturography for evaluating risk of falls in elderly unstable patients

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ABSTRACT

Objective: The aim of this study was to evaluate a screening protocol for detecting potential fallers among elderly individuals with instability, using objective indicators of dynamic equilibration performance.
Material and methods: Dynamic balance in 273 patients with postural instability (59 with and 214 without a history of falls) older than 60 years of age were tested using the SPS (SYNAPSYS) posturography platform, which evaluates equilibration responses to induced postural disturbances.
Results: Among nonfallers, 23% exhibited dynamic balance alterations as severe as those in same-aged fallers. Potential fallers were detected with 97% sensitivity and nonfallers with 77% specificity. Positive and negative predictive values were 54% and 99%, respectively.
Conclusions: The protocol required 5 to 8 minutes. It produced valuable information on postural deficiencies in potential fallers. It is reliable for evaluating the risk of falls in elderly patients with instability. The postural deficiencies identified by our protocol would help to develop effective rehabilitation programs.

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Keywords: Postural balance, Falling risk, Elderly unstable patients, Dynamic posturography, Moving platform.

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INTRODUCTION

Every year, 30% of individuals older than 65 years of age fall at least once [1]. Falls significantly increase the risk of death in the elderly [2-3], cause potentially serious lesions [4-5], and may leave psychological scars, the overall result being impaired self-sufficiency in moving about [6]. Because falls are common, generate substantial mortality, and cause lesions that are costly to manage, they constitute an enormous public health burden. Thus, maintaining a high level of locomotor self-sufficiency is a key objective of the management of elderly patients.

Early detection of potential fallers followed by appropriate rehabilitation and recommendations about fall prevention should substantially reduce the burden related to falls while improving the quality of life of elderly individuals.

Many studies used partly subjective clinical observations to assess the risk of falls [7-10]. We evaluated the effectiveness of objective findings from a dynamic posturography protocol in identifying elderly patients at high risk for falling. We compared fallers and nonfallers in order to identify the stimulation parameters (velocity and frequency of platform motion) and response quantification parameters that best differentiated the two groups. Then, for each of these parameters we determined the cutoff value, defined as the upper limit of the 95% confidence interval of the mean in the group of nonfallers. Values above the cutoff were considered abnormal. Combining several parameters improved the sensitivity and specificity of posturography. Based on the results, we developed four criteria for evaluating the risk of falls in elderly individuals with chronic instability.

This paper describes the screening protocol and the four criteria for risk evaluation developed from our objective evaluation of dynamic balance in individuals with or without a history of falls.

MATERIAL AND METHODS

Sujets

We studied 273 patients older than 60 years of age who presented with postural instability but had normal findings from bithermal caloric tests (Freyss diagram asymmetry less than 15% based on the slow phase velocity of the nystagmus) and symmetric nystagmus during rotation (directional preponderance <1 °/s). Community-dwelling individuals able to ambulate without assistive devices were eligible if they had normal cognition defined as a Mini-Mental Score greater than 24. Mild sedation (e.g., 1/2 bromazepam tablet/24 h) was used by 128 (47%) patients.

Of the 273 study patients, 214 (124 [58%] women, mean age 72.1±6.3 years) had a negative history for falls. Each of the remaining 59 patients (45 [76%] women, mean age 74.47±9.58 years, same age as nonfallers [$F=3.35$, $P<0.07$) reported at least two falls that were not explained by external events, were not associated with loss of consciousness, and were not related to sudden onset of paralysis, a seizure, or heavy drinking.

We excluded patients with uncorrected visual function disorders and those with established vestibular, neurologic, metabolic, vascular, or psychiatric disease.

None of the study patients had a recent history of fractures or sprains, and none had residual abnormalities from fractures or sprains in the more distant past.

Translational platform

Dynamic postural control was evaluated using the SPS (SYNAPSYS, Marseille, France). This platform serves to induce destabilizing perturbations. Responses designed to restore balance are assessed based on measurements of pressure center displacements (for a detailed description, see [11]).

Posturography protocol

The protocol included a translational ramp test at a speed of 0.1 m/s, sinusoid tests at frequencies of 0.25 Hz and 0.50 Hz, and an evaluation of limits of stability. Ramp and sinusoid stimulations were delivered in the anteroposterior direction, with the eyes open and closed, in random order. Patients were instructed to keep their balance without moving their feet. Limits of stability were evaluated on a static platform: patients had their eyes open and swayed as far as possible in all directions while keeping their body straight and without moving their feet or falling. With this method, the ankle strategy is used to maintain balance (upside down pendulum).

Study parameters

Energy of postural responses was used to assess responses to ramp stimulations, using the equation $E = 1/2\ mV^2$, where m is body weight and V is the summation of elementary velocities on the stabilogram during the 8-second stimulation. Time to restabilization was measured as the time from translation onset to restoration of a stabilogram signal indicating a stable position (±2 mm). Responses to sinusoid stimuli were assessed using gain and phase. Gain is the ratio of postural response amplitude over stimulus amplitude. Phase is the difference in degrees between the stimulation peak and the response peak. These parameters were measured for center of pressure displacements in the stimulation plane (Y) and in the perpendicular plane (X). Limits of stability were quantified as the surface area of the shape containing the maximum voluntary center-of-pressure displacement points (Smax).

Statistics

The parameters from the first 202 patients (143 nonfallers and 59 fallers) were subjected to analysis of variance (ANOVA) with nonfaller vs. faller as the between-group factor and eyes open vs. eyes closed as the within-group factor. For the sinusoid stimulations, frequency (0.25 Hz vs. 0.50 Hz) was also a within-group factor. Smax was evaluated using ANOVA with nonfaller vs. faller as the only factor.
Tukey's HSD post-hoc test was used to evaluate the impact of group (nonfaller vs. faller) in each test condition (eyes open vs. eyes closed and 0.25 Hz vs. 0.50 Hz), and results were considered significant when p was less than 0.05.

The results from these evaluations were used to develop the protocol for detecting individuals at high risk for falling. This protocol was validated in 273 patients (214 nonfallers and 59 fallers). Sensitivity was computed as Vp/(Vp + Fn) and specificity as Vn/(Fp + Vn), where Vp and Vn are the numbers of true positives and true negatives, respectively, and where Fp and Fn are the numbers of false positives and false negatives, respectively. Positive predictive value (PPV) was computed as Vp/(Vp + Fp) and negative predictive value (NPV) as Vn/(Vn + Fn).

RESULTS

Group and visual condition were the main sources of significant variations in energy, restabilization time, and gain in X and Y (Table I). An overall group effect [F1.18=31.84 ; P<0.0005] was noted for Smax.

Table I: Statistical evaluation of dynamic posturography parameters : main effect.
Values of F and P showing that group (nonfaller vs. faller) and visual condition (eyes open vs. eyes closed) were the two main sources of significant variation in the dynamic posturography parameters selected for the study. Only the phase of postural responses to sinusoid stimulations failed to significantly discriminate between the faller and nonfaller groups.

Parameters	Sources of variation	
	Group	Eyes open vs. closed
Energy in Y	32.16 (0.05)	58.16 (0.5)
Energy in X	106.08 (0.05)	93.57 (0.05)
Time in Y	7.99 (0.05)	45.85 (0.05)
Time in X	45.09 (0.05)	43.59 (0.05)
Gain in Y	52.03 (0.05)	359.85 (0.05)
Gain in X	25.22 (0.05)	77.59 (0.05)
Phase in Y	1.61 (0.21)	33.88 (0.05)

The detailed results of the statistical evaluation have been reported elsewhere [12]. Only results for effects of the group factor (nonfallers vs. fallers) in each test condition were used to validate the protocol for screening elderly individuals with postural instability. Table II recapitulates the findings from the post-hoc analysis of parameters collected during ramp stimulation with the eyes open and closed. Restabilization time in Y and postural response phase failed to significantly differentiate nonfallers from fallers, in the eyes open and eyes closed conditions. Sinusoid stimulation at a frequency of 0.25 Hz was also unable to detect individuals with a history of falls.

Table III shows the testing protocol developed from the results of the comparative study, as well as the cutoff, sensitivity, and specificity of each selected parameter.

Table II: Statistical evaluation of dynamic posturography parameters: interaction between group and visual condition.
P values showing that ramp stimulations at 0.1 m/s and sinusoid stimulations at 0.50 Hz detected significant differences between the group of fallers and the group of nonfallers. Energy and gain of postural responses in Y and X, as well as restabilization time in X, discriminated between the two groups tested with the eyes open and closed.

Tests	Parameters	Effecte Group	
		Eyes open	Eyes closed
Ramp (0,1 m/s)	Energy in Y	0,05	0,05
	Energy in X	0,05	0,05
	Time in Y	0,06	0,50
	Time in X	0,05	0,05
Sinusoid (0,25 Hz)	Gain in Y	0,82	0,74
	Gain in X	0,99	0,89
	Phase in Y	0,99	0,39
Sinusoid (0,5 Hz)	Gain in Y	0,05	0,05
	Gain in X	0,93	0,05
	Phase in Y	0,92	0,99

Tableau III: Protocol for evaluating the falling risk in elderly patients with chronic postural instability.
Protocol based on the tests and parameters that best differentiated between fallers and nonfallers. Cut-offs for energy (Joules), restabilization time (seconds), gain, and maximal surface area (mm_) correspond to the 95% confidence limits of the means in the group of nonfaller. Selected parameters were sensitive but only moderately specific; Parameters characterizing lateral stability (energy, restabilization time, and gain of responses in X) were more reliable than parameters in Y.

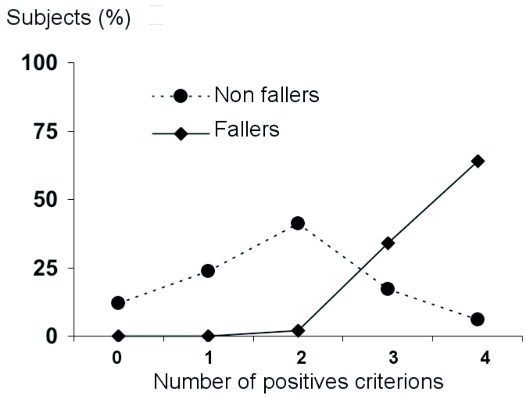
Tests	Parameters	Cut-off	Sensitivity (%)	Specificity (%)
Ramp (0.1 m/s) Eyes closed	Energy in Y	1838 J	76	28
	Energy in X	148 J	98	43
	Time in X	5.49 s	83	32
Ramp (0.1 m/s) Eyes open	Energy in Y	1054 J	76	26
	Energy in X	76 J	80	28
	Time in X	4.23 s	74	36
Sinusoid (0.5 Hz) Eyes closed	Gain in Y	1.96	94	46
	Gain in X	0.50	97	45
Sinusoid Eyes open	Gain in Y	0.86	61	32
Limits of stability	S max	20.000 mm_	83	48

Tableau IV: Criteria for evaluating the risk of falls in elderly individuals with chronic postural instability.
Criteria for being classified as a potential faller. Combining several parameters improved the sensitivity and specificity of posturography testing.

Criteria	Tests	Parameters	Criterion present if:	Sensitivity (%)	Specificity (%)
1	Ramp Eyes closed	Energy in Y Energy in X Time in X	2 or 3 values above the cut-off	92	74
2	Rampe Eyes open	Energy in Y Energy in X Time in X	2 or 3 values above the cut-off	86	76
3	Sinusoid Eyes closed Eyes open	Gain in Y Gain in X Gain in Y	2 ou 3 values above the cut-off	93	63
4	Limites de stabilité	S max	< 20 000 mm_	82	53

Specificity was moderate overall, whereas several parameters showed good sensitivity for distinguishing the group of nonfallers from the group of fallers.
Criteria 1 and 2 relate to the results of ramp stimulations at 0.1 m/s with the eyes closed and open, respectively (Table IV). Each criterion is considered present when at least two of the three relevant parameters are above the cut-off. In the study population, criterion 1 was present in 26% of nonfallers and 92% of fallers, and criterion 2 was present in 24% of nonfallers and 86% of fallers. Criterion 3 reflects the results of sinusoid stimulation at 0.50 Hz with the eyes open and closed. The criterion is present when at least two of the three relevant parameters are above the cut-off (Table III). Criterion 3 was met by 37% of nonfallers and 93% of fallers. Criterion 4 is based on the limits of stability (Table IV), being present when Smax is less than 20,000 mm_. Criterion 4 was present in 47% of nonfallers and 82% of fallers.
Figure 1 shows the distribution of patients according to the number of criteria met. Among fallers, 98% fulfilled three or four criteria, and only 2% met two criteria. In contrast, among nonfallers, 77% met one or two criteria, leaving only 23% with three or four criteria.

Figure 1: Distribution of study participants by number of criteria met.
The overwhelming majority of fallers met at least three criteria, whereas most nonfallers met no more than two criteria.



Presence of at least three criteria for falling had 97% sensitivity for detecting fallers and 77% specificity for detecting nonfallers. The PPV of our screening criteria set was 54% (positive result in 49 nonfallers and 57 fallers). The NPV was 99% (negative result in 165 nonfallers and 2 fallers).

DISCUSSION

Our results show that dynamic postural responses to destabilizing events are significantly altered in fallers compared to nonfallers taken among a population of elderly individuals with instability. However, among self-sufficient elderly nonfallers who are free of serious morbidity but have chronic postural instability, there is a subset of patients whose dynamic postural responses are as severely altered as those in fallers. Many studies indicate that poor balance is a major risk factor for falling [7, 13-14]. Thus, a screening protocol for detecting elderly patients would be extremely useful.

Current methods for evaluating the risk of falling in elderly individuals rely on data from questionnaires and clinical observations that have a subjective component. Furthermore, questionnaire items are not always unequivocally defined. Current risk screening strategies are time-consuming and exhibit only modest sensitivity and specificity [15-17]. Finally, these strategies usually target inpatients, the oldest old, or patients with multiple co-morbidities.

The protocol described here is designed for the early screening of self-sufficient community-dwelling elderly individuals with chronic postural instability. It relies on objective data obtained using the SPS moving platform, which supplies new dynamic parameters that better distinguish between effects related to normal aging and manifestations of disease [11] or sequels of previous falls [12].

The screening protocol requires only a few minutes. It includes two ramp stimulations (one each with the eyes open and closed) at a speed of 0.1 m/s, two sinusoid stimulations (one each with the eyes open and closed) at a frequency of 0.50 Hz, and an evaluation of the limits of stability on an unmoving platform. The results of the screening test are used to evaluate four criteria. Presence of three of these four criteria had 97% sensitivity for identifying fallers and 77% specificity for identifying nonfallers. PPV was 54% and NPV was 99%. In other words, when classifying an elderly patient with chronic postural instability and a negative screen as a nonfaller based on presence of no more than two criteria, the risk of error is only 1%. In our study population, 23% of nonfallers fulfilled three or four criteria. Thus, their dynamic postural responses were as severely altered as those of the fallers.

Although they had a negative history for falls, they can be classified as potential fallers. Such patients should be informed that they are at high risk for falling and should be offered a detailed evaluation and an effective rehabilitation program. This approach can be expected to lighten the public health burden created by falls and to improve the quality of life of elderly individuals.

CONCLUSION

We developed a rapid and effective dynamic posturography screening protocol for evaluating the risk of falls in elderly community-dwelling individuals who have chronic postural instability. This screening approach relies on objective data on dynamic postural responses. The test requires only 5 to 8 minutes. Sensitivity for identifying fallers is 97% (NPV 99%) and specificity for identifying nonfallers is 77%. In addition, our screening test supplies valuable information on specific postural deficiencies that could serve as a template for designing rehabilitation programs.

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