Assessment of the Risk of Fall, Related to Visual Stimulation, in Patients with Central Vestibular Disorders

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Suárez H, Musé P, Suárez A, Arocena M. Assessment of the risk of fall, related to visual stimulation, in patients with central vestibular disorders. Acta Otolaryngol 2001; 121: 220–224. In order to assess the influence of visual stimulation in the triggering of imbalance and falls in the elderly population, the postural responses of 18 elderly patients with central vestibular disorders and clinical evidence of instability and falls were studied while receiving different types of visual stimuli. The stimulation conditions were: (i) no specific stimuli; (ii) smooth pursuit with pure sinusoids of 0.2 Hz as foveal stimulation; and (iii) optokinetic stimulation (OK) as retinal stimuli. Using a platform AMTI Accusway platform, the 95% confidence ellipse (CE) and sway velocity (SV) were evaluated with a scalogram using wavelets in order to assess the relationship between time and frequency in postural control. Velocity histograms were also constructed in order to observe the distribution of velocity values during the recording. A non-homogeneous postural behavior after visual stimulation was found among this population. In five of the patients the OK stimulation generated: (i) significantly higher average values of CE (> 3.4 ± 0.69 cm²); (ii) a significant increase in the average values of the SV (> 3.89 ± 1.15 cm/s) and a velocity histogram with a homogeneous distribution between 0 and 18 cm/s; and (iii) a scalogram with sway frequencies of up to 4 Hz distributed in both the X and Y directions (backwards and forwards and lateral) during visual stimulation with arbitrary units of energy density > 5. These three qualitative and quantitative aspects could be “markers” of visual dependence in the triggering of the mechanism of lack of equilibrium and hence falls in some elderly patients and should be considered in order to prevent falls and also to assist in the rehabilitation program of these patients. Key words: central vestibular disorders, falls, optokinetic stimulation, postural responses, visual dependence.

INTRODUCTION

Equilibrium disorders and falls are one of the most frequent pathologies leading to impaired quality of life and even death in the elderly population (1). In elderly patients with central vestibular disorders (CVD) different elements may trigger lack of balance and falls. A mechanical factor such as muscle weakness as well as wrong information from the altered sensory receptors also need to be considered (2, 3). However, in this population, we must assess how the sensory information is processed in the central nervous system in order to obtain accurate postural and gait strategies. In this way “visual dependence” (4) and “visual vertigo” (5) with postural disturbances, elicited from changes in the visual information (6), have been described. Two different types of visual information are used in the perceptual processes connected with postural and gait control: the global velocity and optic flow (7). Global velocity requires processes which integrate velocity information for relatively large regions of the visual field and operates primarily in the peripheral visual field. Optic flow involves the recovery of accurate speed and trajectory information within the visual field and operates in the central visual field.

Our goal is to evaluate the postural responses in a population with CVD and a history of lack of balance and falls, by reproducing “environmental visual information”, in order to explain the different roles played by the visual factor in the triggering of instability in these patients.

MATERIALS AND METHODS

Patients

Postural behavioral responses to visual stimuli were analyzed in a group of CVD patients (n = 18; 72–84 years old), who had had more than two falls in a year. Central vestibular alterations were recorded by electronystagmography (ENG), searching for spontaneous nystagmus, quantitative and qualitative measures of smooth pursuit, optokinetic nystagmus, vestibulo-ocular reflex and its visual suppression, as described previously (8). All patients were also assessed with audiological testing and MRI or CT. Patients with Parkinson’s disease, musculoskeletal disturbances and dementia were excluded. All patients gave their informed consent. A group of 24 volunteers (41–72 years old) was used as a control.
Method

The stimulation conditions used were: (i) standing position without stimulation and with eyes open; (ii) foveal stimuli: pure sinusoids of 0.2 Hz (1 m distance from LED bar); (iii) retinal stimuli: optokinetic (OK) stimulation at 65°/s angular velocity. The postural responses were measured with an AMTI Accusway platform with online recording of the center of pressure (COP), measuring two relevant parameters: sway velocity (SV) and 95% confidence ellipse (CE).

SV

An 80 s trial was recorded, producing 2 discrete signals of \( n = 4,000 \) samples [sampling frequency \( \left( f_s \right) \approx 50 \text{ Hz} \): COPx and COPy. Then, for each recording, the average speed of COP along its path \( \langle \ddot{v} \rangle \) was calculated at \( t = 10 \text{ s} \) \( (n = 500) \) and \( t = 80 \text{ s} \) \( (n = 4,000) \) using:

\[
\langle \ddot{v} \rangle = \frac{\sum_{i=1}^{N} \left[ \left( \text{COP}_{x,i} - \text{COP}_{x,i-1} \right)^2 + \left( \text{COP}_{y,i} - \text{COP}_{y,i-1} \right)^2 \right]^{1/2}}{N - 1}
\]

A velocity histogram was constructed for all three stimulation conditions.

CE

The CE of the bivariate distribution \( (\text{COP}_{x,i}, \text{COP}_{y,i}) \), \( 1 \leq i \leq N \), is the ellipse wherein 95% of the COP samples are predicted to be enclosed. It can be shown that the area of the 95% confidence ellipse is:

\[
\text{Area} = 2\pi F_{0.05;2N-2} \sqrt{\sigma_x^2 \sigma_y^2 - \sigma_{xy}^2}
\]

where \( F_{0.05;2N-2} \) is the \( F \) statistic at the 95% confidence level with \( N \) data points, \( \sigma_x^2 \) and \( \sigma_y^2 \) are the variances of the ML and AP coordinates, respectively and \( \sigma_{xy} \) is the covariance. For a large sample size \( (N > 120) \) \( F_{0.05;2N-2} \) is 3.00. This is the case here \( (N = 4,000) \).

Time–frequency analysis (scalogram)

In order to evaluate the fundamental oscillatory frequency, its amplitude and the temporal behavior of the responses, a time–frequency analysis of COP in both directions (COPx and COPy) was performed, by computing its scalogram. As the Fourier Transform is not adapted to the analysis of non-stationary signals such as the COP signal, its time–frequency representations must be considered. Because of its resolution properties, a widely-used time–frequency energy density is the scalogram. The scalogram of a signal \( x(u) \) is the energetic version of the Wavelet Transform (WT), defined as the square magnitude of the WT:

\[
\text{SCAL}_x(t,f) = \left| \int_{-\infty}^{+\infty} x(u) \cdot \frac{1}{\sqrt{f_0}} \psi^* \left( \frac{u-t}{f_0} \right) \right| du
\]

The mother wavelet \( \psi(u) \) that was chosen was the Morlet wavelet (4):

\[
\psi(u) = e^{-u^2/2} \cdot e^{j2\pi f_0 u}
\]

This wavelet is the one with the best time–frequency localization in the sense specified by the Heisenberg–Gabor uncertainty principle (9).

Significant changes in the CE and SV were determined using Student’s \( t \)-test for independent samples and an alpha value of \(< 0.05\) was accepted as the level of significant error.

RESULTS

The postural behavior of the 18 CVD patients was not homogeneous. In the main group of 13 patients (Group A), although on average the values of SV and CE were higher after visual stimulation than those of the control group the increase was not significant. In the other group (Group B) of five CVD patients, the OK stimulation produced significantly higher values of CE and SV \( (p < 0.01) \) (Table I; Fig. 1). In four of the five patients in Group B, ENG showed asymmetry of the OK nystagmus, with significant directional preponderance.

<table>
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<th>Table I. Mean values (± SD) of CE and SV under the three stimulation conditions: (i) no stimulation; (ii) smooth pursuit; (iii) OK stimulation</th>
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<td>Stimulation condition</td>
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Fig. 1. Area evolution. CE of the COP distribution (cm²) during 80 s recording under three stimulation conditions: (◯) no stimulation; (□) smooth pursuit; (□) OK stimuli.

Another clinical feature is that all five patients in Group B reported dizziness and a greater lack of balance in large, crowded spaces such as shopping malls, etc. All the patients in Group A adjusted their postural control mainly in the Y direction (backwards and forwards) when undergoing visual stimulation. However, the patients in Group B showed a distribution of sway frequencies in both the X and Y directions (backwards and forwards and lateral) during stimulation.

The scalogram allows us to observe another differential element. In Group A the sway frequency was < 2 Hz, with amplitudes not greater than four arbitrary units of energy density (AUED), whilst in Group B adjusting postural frequencies were > 3 Hz on both axes and with amplitudes of up to 10 AUED (Fig. 2). The velocity histogram also revealed differences: the patients in Group B showed a greater dispersion of values at velocities which were significantly higher ($p < 0.01$), mainly when undergoing OK stimulation (Fig. 3).

**DISCUSSION**

In societies with an increasing number of elderly people, there is also an increase in the pathologies connected with aging. The sequelae of equilibrium disorders, such as bone fractures, head trauma and others, are of fundamental importance and leave a
Fig. 3. Analysis of sway velocity for the three stimulation conditions: (V1) no stimulation; (V2) smooth pursuit; (V3) OK stimuli. Left-hand column: velocity evolution (cm/s) during 80 s recording. Right-hand column: velocity histogram. Arrows indicate when the foveal or OK stimuli were triggered (20 s). Group A showed a mean velocity of 2.2 cm/s while Group B reached velocities of up to 18 cm/s with a homogeneous distribution.

significant number of people with disabilities, with resulting social and economic consequences.

In order to assist with preventative measures, it is highly important to know in which way environmental factors influence the origin of falls and trauma. Patients with different types of central nervous system disease or strabismus symptoms (5) have shown inappropriate postural reactions under conditions of environmental stimulation which reduce their ability to solve sensory conflict.

Our group of CVD patients did not show homogeneous behavior. In five of them, OK stimulation produced a more significant increase ($p < 0.01$) in SV and CE after stimulation. In four of them, the ENG recording showed asymmetric responses with directional preponderance in the OK nystagmus, suggesting a possible relationship between this reflex disturbance and bad resolution of the visual conflict for postural control.

Although the smooth pursuit condition also produces increases in SV and CE, such increases are lower than with OK stimulation in all of the patients studied. This postural behavior suggests that certain visual stimuli can act as risk factors for lack of balance and falls.

As a result of this quantitative assessment of postural control during visual stimulation, we propose three markers to indicate “visual dependence” and risk of fall:

1. An increase in the CE to significantly higher values ($> 3.4 \pm 0.69$ cm$^2$) with OK stimulation;
2. A significant increase in the SV ($> 3.89 \pm 1.15$ cm/s), with a histogram showing a distribution of values between 0 and 18 cm/s;
3. Sway frequencies, evaluated by means of the scalogram (Morlet wavelets), distributed on both axes (X and Y) and extended to higher frequencies (up to 3 Hz) during visual stimulation with AUED values $> 5$.

In the five patients in Group B with these postural responses, sensory conflict was enhanced when receiving a type of visual information which required the integration of information velocities in large regions of the visual field, as occurs with OK stimulation. These three markers should therefore be taken into account in order to understand the mechanism triggering dizziness and falls in some CVD patients with visual dependence. This may lead to the prevention of falls and to the development of a specific rehabilitation strategy.

REFERENCES


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