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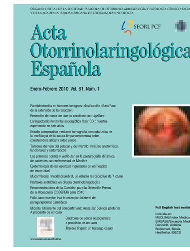

ORIGINAL ARTICLE

Normal and vestibular patterns in dynamic posturography in patients with Ménière's disease

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KEYWORDS
Vertigo;
Dizziness;
Instability

Abstract
Introduction: The Sensory Organization Test of dynamic posturography allows a reliable assessment of the ability of any given patient to maintain correct stability when conditions in the visual surrounding and/or support surface are deliberately modified. The results of this test can be analysed according to the norms of the manufacturer of the device or through the application of specific formulae such as those by Cevette.
Objectives: To evaluate if the Cevette formulae distinguish correctly between the normal and vestibular patterns, as well as observing the differences between these two groups of patients (normal and vestibular), obtained either through standardised calculation or by the Cevette formulae. The study has been restricted to patients diagnosed with unilateral Ménière's disease who presented an active form of the disease and who had not suffered a recent crisis.
Material and methods: Sixty-three patients who fulfilled our inclusion criteria were studied, performing clinical and instrumental audio-vestibular analyses. The results of the sensory organization test were analysed according to the pattern offered by the device and through the application of the Cevette formulae.
Results: In 63 patients, the pattern obtained was normal or vestibular. In 41, the patterns obtained through one analysis system or the other coincided, but in 22 they did not. The analysis of patients using the Cevette formulae offered a higher capacity for clinical discrimination but was not sensitive to the bias introduced by age; however, combined with the classification offered by the device, it managed to differentiate two populations (normal and vestibular) with a very good audio-vestibular correlation.

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Conclusion: The combined assessment of the results of the sensory organization test using both the equipment analysis and the Cevette formulae provides much better, real information on clinical differences among patients with Ménière's disease when the result is normal or of vestibular deficiency.

PALABRAS CLAVE
Vértigo;
Inestabilidad;
Desequilibrio

Los patrones normal y vestibular en la posturografía dinámica de pacientes con enfermedad de Ménière

Resumen
Introducción: La prueba de organización sensorial (POS) de la posturografía dinámica permite hacer un estudio fiable de la capacidad del paciente para mantener una estabilidad adecuada cuando las condiciones del entorno visual y/o de la superficie de apoyo son deliberadamente modificadas. Los resultados de esta prueba se pueden analizar de acuerdo con las normas del equipo o mediante la aplicación de fórmulas particulares como es el caso de las de Cevette.
Objetivos: Valorar si las fórmulas de Cevette disciernen satisfactoriamente entre el patrón normal y el vestibular, así como ver las diferencias entre estos dos grupos de pacientes (normal y vestibular), obtenidos ya sea a partir del cálculo estandarizado como mediante las formulas de Cevette. Se ha restringido el trabajo a pacientes diagnosticados de enfermedad de Ménière unilateral que presentaran una forma activa de la enfermedad y que no hubieran sufrido una crisis recientemente.
Material y métodos: Se estudiaron 63 pacientes que cumplían los criterios para este estudio. Se realizó un estudio audio-vestibular clínico e instrumental. Los resultados de la POS se analizaron a partir del patrón ofrecido por el equipo y tras la aplicación de las fórmulas de Cevette.
Resultados: En 63 pacientes el patrón obtenido fue normal o vestibular. En 41 pacientes el patrón obtenido por uno o por otro sistema de análisis era coincidente, pero en 22 no. La categorización de los pacientes mediante el uso de las fórmulas de Cevette aporta una mayor capacidad de discriminación clónica, pero es sensible al sesgo introducido por la edad; ahora bien, combinado con la clasificación que aporta el equipo logra diferenciar dos poblaciones (normal y vestibular) con una muy buena correlación audio-vestibular.
Conclusión: El análisis de la POS, siguiendo las normas aportadas por el equipo complementado con las fórmulas de Cevette, aporta una información más real de las diferencias clínicas en pacientes con enfermedad de Ménière cuando el resultado es normal o de déficit vestibular.

Introduction

Posturography is a clinical tool that enables a study of postural control. Maintaining balance is achieved through integration into the central nervous system of the information received from three major adaptive sensory systems (vestibular, visual and somatosensory). In computerised dynamic posturography (CDP) and, more specifically, in the sensory organization test (SOT), the contribution of each of the three sensory systems can be analysed separately. To do this, the contribution of each of the inputs or of several together is altered through changes in a mobile platform and a mobile environment where the subject is placed and where he/she must maintain stability. From the results in each of the six study conditions that can be created artificially, we obtain an overall stability value, which is a percentage of the normal value that any given healthy subject should have. In addition, a series of patterns are also defined by dividing the results of each condition by the values and Condition 1 (eyes open, stable support surface and visual environment also stable).

There are other proposals to assess the posturography behaviour of a patient that are also based on the calculation of certain values using different exploration results. One of the most commonly used is that of Cevette,[1] which aims to catalogue, in a simple manner, whether the pattern of a patient is "normal", "vestibular" or "aphysiological". There is a specific formula to define each pattern, which uses some SOT conditions modified by a factor and added to a certain constant (Table 1); these operational values are derived from a discriminating analysis performed to discriminate simulating patients. Thus, each patient obtains three values derived from the application of each of these formulae, and the pattern that defines the final outcome of the subject or patient is that with the highest value. The clinical correlation or level of accuracy of this method is varied, as summarised below. An attempt by a normal subject to simulate a vestibular or aphysiological pattern (stimulating the ear with cold water) applying the Cevette formulae is classified correctly in 75% of the studies.[2] A well-rehearsed simulation or one with no preparation produce no differences in outcome in the aphysiological pattern.[3] The definition of the aphysiological

Table 1 Calculation of the Cevette formulae

Normal	$-238.14+(2.24*Eq_{SOT1})+(1.45*Eq_{SOT2})+(1.74*Eq_{SOT4})-(0.13*Eq_{SOT5})$
Aphysiological	$-158.2+(1.94*Eq_{SOT1})+(1.09*Eq_{SOT2})+(1.37*Eq_{SOT4})-(0.15*Eq_{SOT5})$
Vestibular	$-251.21+(2.31*Eq_{SOT1})+(1.54*Eq_{SOT2})+(1.89*Eq_{SOT4})-(0.58*Eq_{SOT5})$

Eq: result in the study condition; SOT: sensory organization test

pattern is appropriate in patients when there is prior, founded suspicion, and should be correlated closely with the anamnesis and other psychopathological data from the vestibular exploration.[4] In the case of patients with dizziness and/or posttraumatic imbalance (work-related and with possible monetary compensation), the definition of the patients according to the Cevette formulae does not distinguish them from a second group (slightly less numerous) of patients with imbalances due to other causes. Furthermore, the Cevette formulae do not distinguish satisfactorily between an aphysiological pattern and a patient with vestibular disease.[5]

Patients with Ménière's disease show a larger swivel area than control subjects and a significant distortion in the amplitude of the stability limits and the internal scheme.[6] Indeed, in some subjects, the swivel is greater with their eyes open than closed[7]. Finding a statistically significant correlation of the CDP parameters with respect to the time elapsed since the last vertigo crisis is of great importance.[8] Accordingly, a range of probable values of the CDP parameters were proposed and three categories of disease activity were established. These categories classify patients into: "recent post-attack" (less than a week since the last episode of vertigo), "late post-attack" (one week to 60 days since the previous attack) and "inactive" (when more than 60 days have passed since the last crisis suffered by the patient. The results show significant differences depending on the length of time since the last attack: it is generally clear that there is moderate correlation between CDP values and the time elapsed since the last episode of vertigo. The phenomenon of visual dependence (easily demonstrable in the SOT) is very common in patients with Ménière's disease and, after surgery (vestibular neurectomy), patients change their pattern of preference, from a visual preference to a somatosensory preference and vice versa. The importance of this phenomenon in patient evolution is still unknown, given that it is still not known exactly why a patient will, at a given time, seek further information from either source to maintain stability.

The aim of this study was to assess whether the Cevette formulae satisfactorily discern between the normal and vestibular patterns, as well as to observe the differences between these two patient groups (normal and vestibular), obtained either through standardised calculation or through the Cevette formulae. The study was restricted to patients diagnosed with unilateral Ménière's disease who presented an active form of the disease and who had not recently experienced a crisis (patients who had had a vertigo crisis no earlier than 8 days and no later than 60 days from the time of the examination).

Material and methods

Patients

This retrospective study reviews the results obtained in a population of patients with diagnosis of unilateral Ménière's disease who meet the criteria for disease defined according to the instructions of the American Academy of Otolaryngology-Head and Neck Surgery.[9] To meet our study objectives (vertigo crises between 8 and 60 days before the time of examination), 63 patients were selected from a database of Ménière's disease that stores information about patients seen in our department.

Neuro-otological exploration

In all cases, we carried out a detailed history, a clinical neuro-otological examination and a full audio-vestibular study. The clinical exploration focused on the analysis of spontaneous nystagmus (with and without visual fixation), the vestibulo-oculomotor reflex via the oculo-cephalic manoeuvre and cephalic agitation nystagmus.

Caloric Test

An alternative bithermal caloric test was conducted and nystagmus was recorded with a video-nystagmography device (Ulmer VNG, v.1.4, SYNAPSIS®, Marseille, France). The parameters used were the canalicular paresis and directional preponderance according to the Jongkees formulae; normal values for each were less than 20% and 28%, respectively.

Rotation test

The vestibulo-ocular reflex was studied by impulsive rotating stimulation using a specific computer (CHARTR® RVT system, ICS Medical Corporation, Schaumburg, I11). This computer determined the value of the gain and time constant after at least 3 stimulations towards each side, separating the values obtained for turns towards the healthy and affected sides. The acceleration used was $100º s^{-2}$. Normal values were 0.43 ± 0.08 for gain and 13 ± 4.5 s for the time constant.

Computerised dynamic posturography

For this study, we used the CDP device Equitest Smart System, version 7.0 (Neurocom International, Inc., Clackamas, Oregon). The system consists of a computer, a mobile platform referenced to the movement experienced by the patient during the scan, and a visual environment.

We analysed the results of the SOT that was performed with the patient standing on a fixed or mobile platform and surrounded by an artificial visual environment that was also either fixed or mobile. The support surface of the platform contacted directly with four pressure transducers (two for each foot), symmetrically located to measure the vertical forces exerted, and a central transducer that measured the horizontal forces exerted along the anteroposterior axis in the plane parallel to the ground. Both the platform and the environment could be moved, under computer control, about an axis aligned with the ankle joint. Thus, when desired, the bodily oscillations could cause a movement of the same degree and direction as the platform and/or visual environment.

The study consisted of six independent conditions, each lasting 20 s, and with three attempts in each of them, except in Conditions 1 and 2, which had only 2 attempts. In Conditions 1, 2, and 3, the support surface was fixed, while in 4, 5, and 6 it was referenced to the swivel, that is, it tilted in the same direction and angle as the angle of swivel around the ankle done by the patient, as obtained from the displacement of the centre of gravity. In Conditions 1 and 4, the patient remained with his or her eyes open, while 2 and 5 are performed with eyes closed; and in 3 and 6, with eyes open but with the visual environment referenced to the swivel.

The degree of stability is determined in each condition, and this is calculated by comparing the angular difference between the maximum anteroposterior oscillation of the patient throughout each test and the maximum normal limits of anteroposterior stability. This gives, for each of them, a balance score (Eq_{C1}–Eq_{C6}), based on the assumption that an individual can perform an anteroposterior displacement, without falling, of 12.5º around a pivot centre located in the ankles. The score was calculated by comparing the current maximum displacement of the centre of gravity and that theoretical maximum. The score is offered as a percentage between 0 and 100%, with the first representing a maximum displacement, and therefore the need to take a step in the platform to avoid falling, and the second a minimum or zero swivel with perfect stability.

The total value of balance or percentage of balance and sensory analysis or relative contribution of somatosensory, visual and vestibular receptors in the global stability of patients, as well as their ability to maintain balance with wrong sensory information, can be calculated from the average values obtained in each condition. The normal pattern indicates that the patient is able to perform all the conditions correctly and the value of the composite score is above and over what is considered normal. The pattern of vestibular deficit or vestibular pattern indicates that the patient is unable to maintain good stability when using only vestibular information, whereas having correct visual or somatosensory information improves stability; this is calculated from the relationship between the results in Condition 5 and Condition 1.

Secondly, and to meet our study objectives, we calculated the pattern of sensory deficit according to the Cevette formulae. This author defined three formulae, each of which determines an index value of "normal", "aphysiological" and "vestibular",[1] from the score obtained on any of the 6 SOT conditions. These formulae are presented in Table 1. Applying the results to a patient, the index with the highest value defines the pattern.

Statistical analysis

Patients were classified according to their results in the posturography analysed according to the standards of the device and having applied the Cevette formulae, and only those with normal and vestibular patterns were selected. Statistical analysis was performed using nonparametric tests using the statistics package SPSS (v.13) and differences were considered significant when $P<.05$.

Results

From the data of time in days since the last crisis of vertigo and the posturography findings, we selected the patients with normal or vestibular results as the subjects of this study (n=63). The results coincided in 41 patients (34 with the result of normal and 7 with that of vestibular according to both methods) and were mismatched in 22 patients (5 normal according to the criterion of dynamic posturography and vestibular according to the Cevette formulae and 17 vestibular according to the first and normal according to the second).

Of the 63 patients, 24 were female and 39 were male, and the average age was 50 ± 11 years. The disease affected the right ear in 29 patients and the left in 34. The mean duration of the disease was 5 years (95% confidence interval [CI] of 4-7) and the number of days since the last crisis was 25 days (95% CI: 21-28). The neuro-otological clinical examination was normal in 40%; the abnormal results found were spontaneous nystagmus (35%), vestibular-oculomotor reflex or oculo-cephalic hypometric manoeuvre (25%), cephalic agitation nystagmus (36%) (8% of all the results were abnormal). The average audiometric tone threshold in the diseased ear was 57 dB HL (hearing level) (95% CI: 52-62) and in the healthy ear, it was 20 dB HL (95% CI: 16-25); the percentage of discrimination in the diseased ear was 82% (95% CI: 77-87) and in the healthy ear it was 96% (95% CI: 95-98). The caloric test was normal in 25 patients (39.7%) and abnormal results found were canalicular paresis (54%) and directional preponderance (23%) (both results were abnormal in 18% of patients). In the rotational test, the value of the gain with the turns towards the diseased side was 0.42 ± 0.14 and towards the healthy side it was 0.44 ± 0.13; the time constant with rotations towards the diseased side was 14 ± 7s and, towards the healthy side, it was 15 ± 7s.

Table 2 presents the results of the various auditory and vestibular parameters as well as those of disability. They were grouped according to the result (normal or vestibular) depending on the method of analysis used: according to directions of the device (the SOT) and applying the Cevette formulae, and those showing significant differences were highlighted. Figures 1 and 2 show the results for each condition indicated by the SOT and the Cevette formulae, respectively. Values are presented for patients classified as normal or vestibular according to the directions of the device (SOT) or applying the Cevette formulae. The statistical analysis attempted to assess the existence of significant

Table 2 Results obtained in each group by applying the assessment given by the rules of the sensory organization test (SOT) device or after application of the Cevette formulae

	SOT		Cevette	
	Normal	Vestibular	Normal	Vestibular
Age	48 ± 11	52 ± 13	47 ± 10	57 ± 13
Tdur	5 ± 5	6 ± 5	5 ± 5	7 ± 7
Tactiv	23 ± 12	23 ± 9	23 ± 12	23 ± 16
NC	8 ± 8	8 ± 5	7 ± 5	10 ± 10
ATT aff	52 ± 21	60 ± 16	53 ± 19	63 ± 18
DISCR aff	83 ± 18	80 ± 16	81 ± 18	81 ± 16
ATT hea	15 ± 10	27 ± 17	18 ± 13	28 ± 19
DISCR hea	97± 4	95 ± 7	97 ± 4	94 ± 8
CP	37 ± 28	33 ± 22	35 ± 24	36 ± 22
DP	18 ± 13	17 ± 13	17 ± 12	19 ± 14
G aff	0.39 ± 0.14	0.41 ± 0.15	0.41 ± 0.15	0.38 ± 0.14
G hea	0.4 ± 0.13	0.4 ± 0.14	0.41 ± 0.15	0.38 ± 0.12
TC aff	16 ± 7	13 ± 7	15 ± 7	12 ± 6
TC hea	16 ± 7	14 ± 8	15 ± 7	14 ± 7
CS	78 ± 5	61 ± 7	74 ± 8	61 ± 12
DHI	36 ± 16	43 ± 24	38 ± 18	40 ± 25
Yint	13 ± 8	12 ± 9	12 ± 7	15 ± 11
Yanx	14 ± 9	15 ± 11	14 ± 10	14 ± 9

ATT: audiometric Average Tone Threshold in decibels (dBHL) (aff: affected ear; hea: healthy ear); CP: canalicular paresis (%); CS: composite score of the sensory organization test; DHI: total score on the DHI; DISCR: percentage of discrimination; DP: directional preponderance (%); G: Gain of the VOR (vestibulo-oculomotor reflex) in the impulse test (aff: acceleration towards affected ear; hea: acceleration towards healthy ear); NC: number of crises in the past 6 months; Tactiv: Time since last crisis (days); TC: time constant in seconds (aff: acceleration towards affected ear; hea: acceleration towards healthy ear); Tdur: Time of duration of illness (years); Yanx: somatic anxiety according to the Yardley questionnaire; Yint: intensity of vertigo according to the Yardley questionnaire.

differences in the results of patients with different patterns in each analysis system or in patients with the same pattern but in different analysis systems.

Finally, the results were analysed in the matching group and in the group with different outcomes. In the first, in terms of differences in clinical parameters between patients with normal and vestibular patterns according to the directions of the device, the differences were established in the value of the average audiometric tonal threshold, both of the diseased and the healthy ear, in the result in SOT Conditions 4, 5, and 6, in the overall value (composite score) and the vestibular formula. When patients were classified according to the Cevette formulae, the differences were only for Condition 5, composite score and vestibular formula. In the second group, among patients with normal vestibular result, both ways of classifying only allowed for differences to be established in Condition 5 and the vestibular formula.

Discussion

We can say that there is certain similarity between the two ways of classifying SOT results, which are rather complementary. Before detailing the findings, it is necessary to mention that the time elapsed since the last crisis until the time of exploration is a very relevant fact in studies of patients with Ménière's disease, because it determines much of the dynamic posturography results. For this reason, we decided to narrow the patient group for our study to those in a situation neither too acute nor inactive; the subjects are thus patients who have had dizzy spells no earlier than 8 days and no later than 60 days prior to analysis and have been termed as late post-attack.[8]

In patients with active non-acute Ménière's disease, it is observed that the normal pattern, (determined either by conventional means or by applying the Cevette formulae) is the most common pattern, a fact already noted by other authors.[10] The normal pattern suggests that patients make appropriate use of sensory information to maintain stability. For its part, the vestibular pattern (which is itself a pattern of vestibular functional deficit) indicates that the patient is unable to maintain correct stability when using vestibular information alone, but does improve stability when there is accurate visual or somatosensory information.

In analyzing the clinical parameters and those of the vestibular-ocular examination, a common phenomenon is found: the lack of correlation between clinical findings and those of dynamic posturography in patients whose main symptom is vertigo located peripherally.[11] From our study, we can say that the classification based on the Cevette formulae established two populations (normal and vestibular) that have more differences between them than when classified according to device guidelines. It is noteworthy that patients with vestibular pattern have an

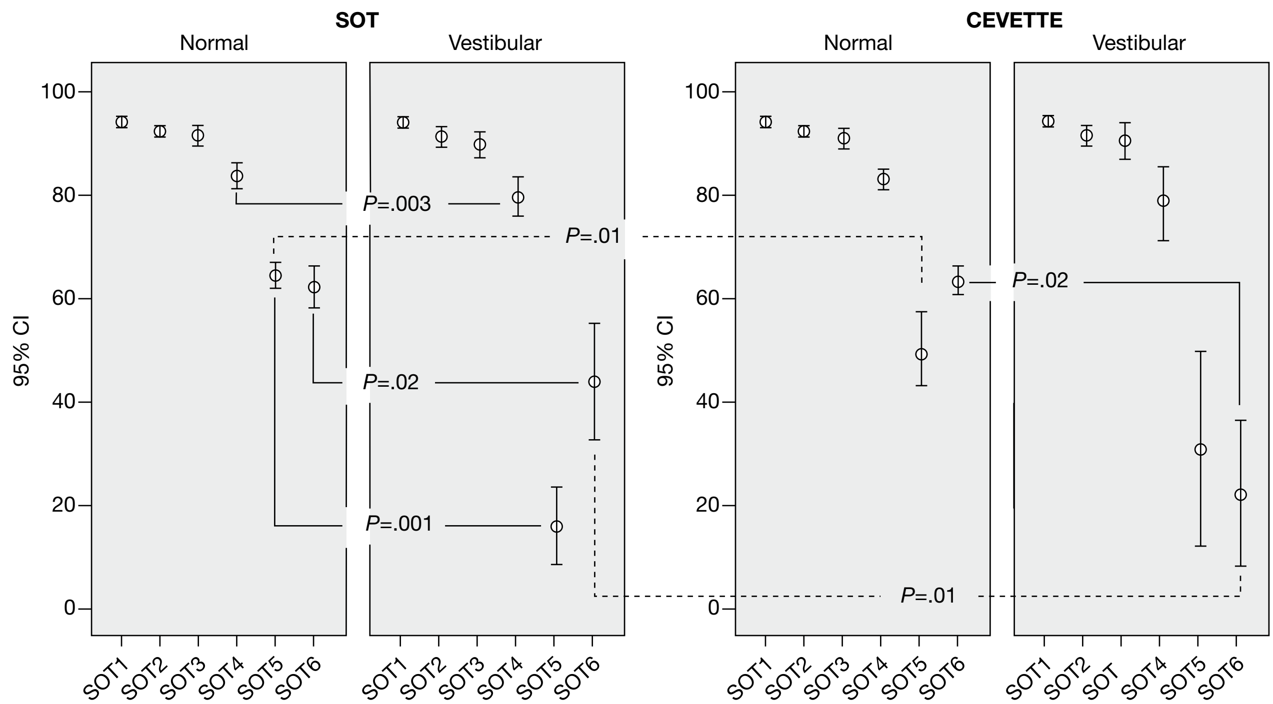

Figure 1 Value in the conditions of the sensory organization test (SOT) of the dynamic posturography. These are presented for the classification provided by the system and after applying the Cevette formulae. The values shown are those that reflect significant differences. CI: confidence interval.

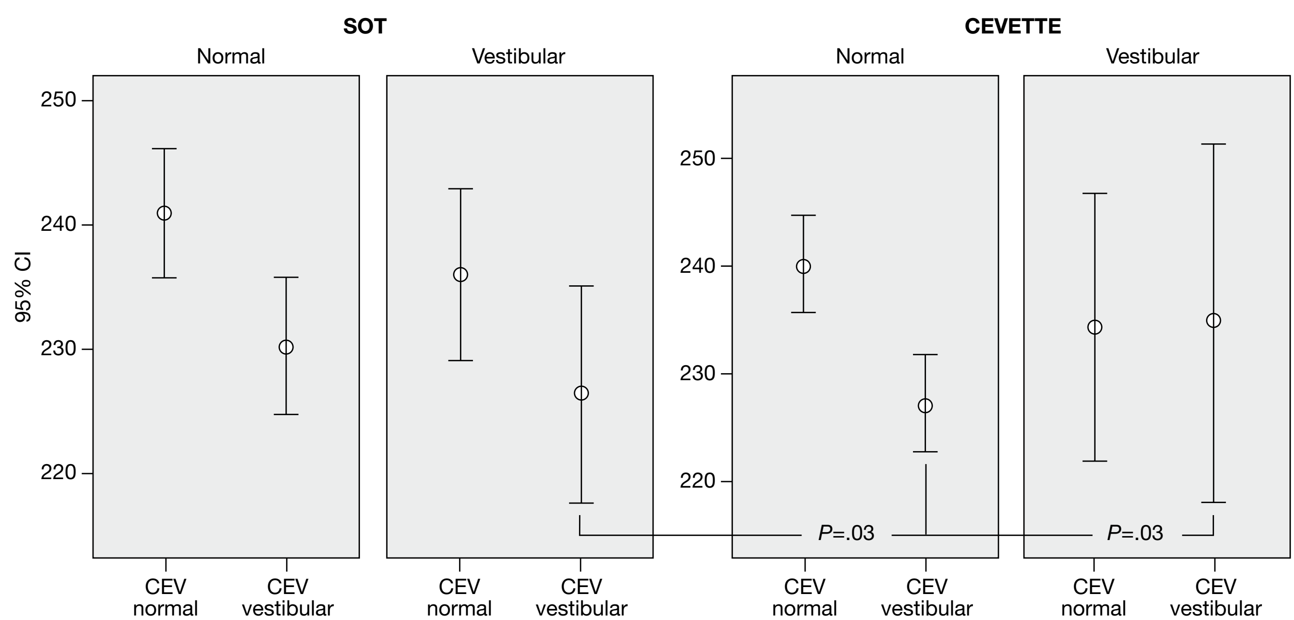

Figure 2 Values of Cevette formulae. These are presented for the classification provided by the system and after applying the Cevette formulae. The values shown are those that reflect significant differences. CI: confidence interval; SOT: sensory organization test.

average audiometric tone threshold significantly higher in the healthy ear and that is also clearly pathological. In the case of patients with vestibular pattern according to the Cevette formulae, this may be due to a probable presbycusis effect, since the average age of theses patients is significantly higher than that of those showing a normal pattern. In the case of patients classified in accordance to the device directions, it raises the question of a possible subclinical contralateral hearing impairment (which does not necessarily imply a clinical bilateral evolution). This is a common finding and has also been found in studies with otoacoustic emissions[12] and vestibular evoked myogenic potentials.[13] The overall balance value (composite score) is significantly lower in patients with vestibular pattern;

that is expected in patients classified according to device directions since it is the basis of its classification system, but argues the capacity of the Cevette formulae to discriminate between both patterns from the posturography standpoint. With respect to the Cevette formulae, in addition to the finding of differences in average patient age, there is a difference in the value of the time constant of the vestibulo-oculomotor reflex with accelerations towards the diseased side. This variation has very low clinical significance because the difference in values is small, almost at the limit of clinical significance, and is correlated with the degree of vestibular function deficit.

When analyzing in detail what condition is established by the differences between the normal and vestibular pattern, it is as expected (vestibular formula) in the case of the Cevette formulae. Furthermore, the result in Condition 6 (Table 1) is the one that exactly distinguishes this formula with the normal. Meanwhile, in the case of the classification based on device directions, the different variables are those that have more weight in the calculation of the overall value and the vestibular pattern (Conditions 5 and 6). This explains why the level of coincidence between results is 65%. Quite significant differences are revealed in analysing this situation. The patient group in which the results match (patients with normal or vestibular result in both classification systems), the differences between clinical parameters, of auditory and vestibular function and the degree of disability is very evident if one follows the classification method based on device directions. Moreover, in this case, the Cevette formulae hardly distinguish between patients. This reflects a fact already mentioned by other authors, who consider that the overall value of balance, or composite score, obtained in the SOT is of limited value as a measure of postural stability and offer alternative methods of analysis, such as the exact weighing of all conditions and/or consideration of other aspects of postural biomechanics.[14] This is what the Cevette formulae do by associating greater weight to Conditions 1 and 2 of the ranking provided by the computer. Therefore, when combining the two systems, an unusual effect is achieved, a better differentiation between audiometric values for both the healthy and diseased ear in patients with normal and vestibular pattern, possibly improving the analysis of audio-vestibular correlation above the current capabilities.[15]

Conflict of interests

The authors declare no conflict of interests.

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