

ORIGINAL ARTICLE

Extratympanic Electrocochleography in Ménière's Disease[☆]

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KEYWORDS

Extratympanic electrocochleography;
Ménière's disease;
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Abstract

Introduction: Electrocochleography is the registration of an electrophysiological event which takes place in the cochlea after an acoustical stimulus. Most of the authors consider an increased summing potential (SP)/action potential (AP) ratio as characteristic of endolymphatic hydrops.

Methods: A longitudinal, prospective study of a unilateral Ménière's population diagnosed according to the American Academy of Otolaryngology–Head and Neck Surgery classification was carried out. A complete clinical history and bedside examination were performed, in addition to complete auditory and vestibular testing and an extratympanic electrocochleography. We selected 20 normal hearing subjects with no history of vestibular and otological pathology as a control group.

Results: Of the 100 patients included in the study, 62 were diagnosed as definite Ménière's disease, and 13 and 25 as probable and possible Ménière's disease, respectively. In the electrocochleography, 85% of all the patients had an SP/AP ratio above 0.5. A sensibility of 92%, 78% and 75% was obtained in the definite, probable and possible Ménière's disease patients, respectively.

Discussion and conclusions: Electrocochleography is a useful method for diagnosing and evaluating patients with Ménière's disease syndrome. It provides information about the progression of the process and shows a significant correlation with the clinical stage.

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PALABRAS CLAVE

Electrococleografía extratimpánica;
Enfermedad de Ménière;
Pruebas vestibulares

Electrococleografía extratimpánica en la enfermedad de Ménière

Resumen

Introducción: La electrococleografía (ECoG) es un registro de un episodio electrofisiológico, que tiene lugar en la cóclea tras un estímulo acústico. La mayoría de los autores consideran que un aumento del cociente SP/AP utilizando clicks, es característico del hidrops.

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Métodos: Presentamos un estudio longitudinal y prospectivo de una población de pacientes con enfermedad de Ménière unilateral definida según los criterios de la Academia Americana de Otorrinolaringología y patología cervicofacial. Tras una correcta anamnesis y exploración otoneurológica completa, todos los pacientes fueron sometidos a un estudio de la función auditiva y vestibular mediante audiometría tonal liminar, pruebas calóricas, rotatorias y una ECoG extratimpánica. Como controles se escogieron 20 sujetos normoacúsicos carentes de antecedentes de afección vestibular u otológica, ni antecedentes quirúrgicos en el oído medio.

Resultados: De los 100 pacientes incluidos, 62 fueron diagnosticados de enfermedad de Ménière definida, 13 de probable y 25 de enfermedad de Ménière posible. Un 85% de la población con enfermedad de Ménière, cumplían criterios electrofisiológicos de enfermedad de Ménière según los parámetros de la ECoG (SP/AP > 0,5). El porcentaje de ECoG alteradas según el diagnóstico era del 92, 78 y 75% para el Ménière definido, probable y posible respectivamente.

Discusión y conclusiones: La ECoG es un método útil para el diagnóstico y evaluación de la enfermedad de Ménière. Aporta información fidedigna del progreso de la enfermedad y existe correlación con su estadio diagnóstico.

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Introduction

As the term itself suggests, electrocochleography (ECoG) is a recording of an electrophysiological episode occurring within the cochlea after acoustic stimulation.

Far from being a new technique, ECoG emerged as a clinical tool in the 1970s, although the first attempts to record the cochlear microphonic potential date from 1930, when this potential was discovered in cats.

Subsequently, the summation potential (SP) was described in animals in 1950, but the first record in humans was not obtained until the decade of the 1970s by Eggermont and Odenthal¹ and Gibson et al.²

The discovery of the clinical applications of brainstem auditory evoked potentials (BAEP) increased the interest in all auditory evoked potentials. This fact, coupled with the development of noninvasive techniques, facilitated the implementation of ECoG as a method of study in many Otorhinolaryngology services and units.³

The indications for study by ECoG are not limited to the study of endolymphatic hydrops/Ménière's disease, as it can also have clinical applications as an auditory study in the paediatric population or for intraoperative monitoring, among others.

The 2 approaches currently available for ECoG recording are the transtympanic and the extratympanic.

Its ease of use, low morbidity and, in most cases, unnecessary presence of a physician, have contributed to the growing presence of extratympanic ECoG in various diagnostic protocols.⁴

It is a proven fact that patients with Ménière's disease usually develop increased SP amplitudes. This is because the increased endolymphatic volume creates an impairment for the vibration capacity of the organ of Corti, to which the SP is sensitive.

Although this finding is frequent, its applicability is greatly reduced by its low specificity, since the values obtained largely overlap with those of the normal population. However, thanks to the relationship established between the SP parameter and the action potential (AP), the diagnostic performance of the test has increased significantly, thus improving its development as a clinical tool.²

In fact, at present most authors believe that an increase in the SP/AP ratio using clicks is characteristic of hydrops.

In an attempt to improve the sensitivity of the test for the diagnosis of Ménière's disease, Devaiah et al.⁵ not only measured the SP/AP ratio, but also the SP/AP area, thereby increasing the sensitivity of the test, according to the author.

In our study we aimed to assess the sensitivity and specificity of ECoG in our population of patients with Ménière's disease and to correlate it with parameters obtained through clinical and vestibular studies.

Material and Methods

We present a prospective and longitudinal study of a population of patients with unilateral Ménière's disease, defined according to the criteria of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS).

The study was conducted between March 2008 and February 2011.

We consecutively studied all patients attending the Otoneurology Service during the study period who met the inclusion criteria.

After a correct anamnesis and complete otoneurological examination, all patients underwent a study of auditory and vestibular function through liminal tone audiometry, caloric and rotational testing and extratympanic ECoG.

Inclusion Criteria

- 1 Patients with unilateral Ménière's disease, classified as definite, probable or possible according to the criteria of the AAO-HNS.
- 2 Correct completion and interpretation of all auditory, vestibular and electrophysiological tests necessary for this study.
- 3 Normoacusis of the contralateral ear.

Exclusion Criteria

- 1 Bilateral involvement or presence of symptoms suggesting involvement of the contralateral ear.
- 2 Symptoms suggestive of the presence of neurological involvement.

- 3 History of middle ear surgery, such as myringotomy, myringoplasty, tympanoplasty or stapedectomy, which could alter the correct interpretation of vestibular tests and ECoG.
- 4 Anatomical abnormalities of the external and/or middle ear likely to affect the implementation and/or interpretation of vestibular and electrophysiological testing.
- 5 Presence of any other vestibular condition other than Ménière's disease in both the affected ear and in the contralateral ear (benign paroxysmal positional vertigo [BPPV], vestibular neuritis, perilymphatic fistula or migraine-associated vertigo).

Normal Group

We selected 20 subjects with normal hearing and with no history of vestibular or otological involvement, nor surgical history in the middle ear.

Anamnesis

The medical records collected the relevant data about the disease of each patient. We included a detailed history of the main symptoms and a review of the medical (previous diagnoses, medical and surgical history) and family history.

The number and duration of episodes, associated symptoms, their duration and functional level recommended by the AAO-HNS were expressly reflected in the personal history.

Physical Exploration

All patients underwent a standard oculomotor assessment through videonystagmography equipment which systematically evaluated the presence of spontaneous, head shaking, positional and positioning nystagmus. All patients underwent the oculocephalic manoeuvre or Halmagyi test, in addition to an assessment using the Romberg and Fukuda tests.

Tone Audiometry

The audiometric threshold by air and bone routes was determined for frequencies of 0.25, 0.5, 1, 2, 3, 4 and 6 kHz within a soundproof booth (IAC mini 250). From the result we obtained the value of the pure-tone average (PTA) at frequencies of 0.5, 1, 2 and 3 kHz, as recommended by the AAO-HNS, as well as the PTA for all frequencies studied.

As recommended by the AAO-HNS, we entered into the database the worst audiometry obtained within the period of 6 months before the study.

Vestibular Caloric Tests

All patients underwent caloric testing at the time of inclusion in the study. We used a VN415 module, 2-channel VNG device, from Interacoustics®.

The type of caloric stimulation used was based on the methodology described by Fitzgerald and Hallpike in 1942. Its aim was to stimulate the horizontal semicircular canal

(HSC) on each side at different temperatures. This generated a nystagmic response in opposite directions, which allowed us to determine the reflex activity from each ear, as well as its integration in the central nervous system (CNS). This procedure has been described in previous publications.⁶

Vestibular Rotatory Tests

We distinguished the sinusoidal harmonic acceleration rotary test and the impulse rotatory test according to the type of stimulus and temporal presentation.

Impulse Rotatory Test

Procedure. In order to obtain an adequate stimulation, patients were placed in a dark environment with the head flexed approximately 30°, so that the semicircular canals were in a correct plane. Patients were then sharply accelerated or decelerated from 0 to 100° s⁻¹ in 1 s. In the case of acceleration, once the desired speed was reached it was maintained constant during 60 s. After this time, the speed was slowed in 1 s and maintained for a further 60 s. This sequence was repeated 3 times towards each side. The postrotatory time constant of each ear was recorded as a parameter.

Sinusoidal Harmonic Acceleration

Procedure. Patients were subjected to a complex and varied stimulus. This was a sinusoidal oscillation in the vertical axis using the following harmonic frequencies: 0.01, 0.02, 0.04, 0.08, 0.16, 0.32 and 0.64 Hz. In each of them, the maximum speed obtained was 60° s⁻¹ and the stimulation cycle was repeated several times. In order to achieve an adequate stimulation, patients were placed in a dark environment with the head flexed approximately 30°, so that the semicircular canals were in a correct plane. In order to minimise discomfort and the time of completion of the test in the present study, the studied frequencies were reduced to 0.16, 0.32 and 0.64 Hz. The values of phase, gain and symmetry of each studied frequency were determined as parameters.

Electrocochleography

All patients underwent the test within an acoustically isolated room, in darkness and with the head flexed towards the contralateral side of the ear being stimulated. The extratympanic electrode was introduced following otoscopic examination and cleaning if necessary. It was also soaked in saline solution and conductive gel in order to minimise discomfort.

All recordings were made with a Smart EP® auditory brainstem response (ABR) device (Intelligent Hearing Systems, Miami, FL, USA).

We used a single-channel recording obtained with a monaural stimulus consisting of 0.1 ms clicks, of alternating polarity at 90 dB, with apportionment of 7.1 s. We obtained 2 recordings for each ear and the evoked potential activity was filtered with a range of 5–1500 Hz. A sweep from 250 to 400 clicks was conducted for each recording in all patients.

Table 1 Stages of Definite Ménière's Disease (AAO-HNS, 1995). Mean Value of Thresholds for Pure Tone Audiogram at Frequencies of 500–1000–2000–3000 Hz, the Worst Audiogram in the Previous 6 Months.

Audiometric Stages	Number of Patients
Stage 1 (<25 dB)	17
Stage 2 (26–40 dB)	23
Stage 3 (41–70 dB)	54
Stage 4 (>7 dB)	6

Statistical Analysis

All the study variables were entered into a database in the statistical package SPSS version 15.

For the descriptive study we performed an analysis of the mean and standard deviations and an analysis of the frequency of occurrence in the contingency tables.

For the comparative study we used a multivariate analysis with Duncan and Scheffé *post hoc* tests.

We used a simple linear regression analysis to study the correlation between the time in months preceding the last crisis and ECoG parameters.

Results

Patients

During the study period, 187 patients diagnosed with Ménière's disease attended our service. Of these, 20 patients were dismissed due to hearing and/or vestibular involvement of the contralateral ear, 31 patients due to a history of middle ear surgery or some anatomical asymmetry affecting the test, 17 due to uninterpretable test records and 17 for not completing the necessary follow-up.

Of the 100 patients included in the study, 57 were female and 43 were male. The mean age was 54.6 years (95% confidence interval [CI]: 49–56.7).

The left ear was affected in 53 patients and the right ear in the rest.

The mean period from the date of the last vertigo crisis prior to the completion of the ECoG was 1.5 months (range: 0.5–5 months).

Following the recommendations of the AAO-HNS, patients were staged according to the prior PTA as shown in Table 1. The PTA obtained from patients before starting the protocol (the worst tone audiometry in the previous 6 months) was 57.25 dB (95% CI: 52.65–61.84).

Of the 100 patients included in the study, 62 patients were diagnosed with definite Ménière's disease, 13 with probable and 25 with possible Ménière's disease, without significant variations between them regarding the duration of disease (Table 2).

Caloric Vestibular Test

The mean value of the degree of canalicular paresis was 36%±22%. Up to 14% of cases presented a directional preponderance in the caloric test.

Table 2 Diagnostic Criteria for Ménière's Disease (AAO-HNS, 1995). Number of Patients in Each Stage According to Our Patient Population.

Diagnosis	Number of Patients
Definite Ménière's disease	62
Probable Ménière's disease	13
Possible Ménière's disease	25

According to the normality values established in our laboratory, patients presented the following diagnoses related to the caloric test:

- Normal: 41%
- Unilateral canalicular paresis: 58%
- Unilateral arreflexia: 1%

Vestibular Rotatory Test

The most frequently observed patterns in our patient sample were:

- Uncompensated acute vestibular deficit pattern: 15 patients
- Compensated acute vestibular deficit pattern: 23 patients
- Habituation pattern: 5 patients
- Normal pattern: 57 patients

Below are the results obtained from the rotational tests.

Impulse Rotatory Test

Table 3 shows the time and vestibulo-ocular reflex gain results with accelerations towards the right and left sides. The values of the right (15.31 s) and left (16.01 s) postrotatory time constants did not display significant variations.

Sinusoidal Harmonic Acceleration

The results obtained in this rotary test are presented in Table 4, in the defining parameters of phase, gain and symmetry, detailed for each stimulation frequency. The mean values obtained for gain significantly increased as the frequency of stimulation increased, without leaving the normality range established in our vestibular laboratory.

Electrocochleography

Based on the upper level of the 95 percentile of a population with 20 normal subjects, we believe that an SP/AP ratio over 0.5 indicates a dysfunction of the internal ear.

Table 3 Mean Gain and Time Constant Values of the Population in the Impulse Rotatory Test.

Time Constant	
Right post-rotatory	15.31 ± 8.3
Left post-rotatory	16.01 ± 8.7

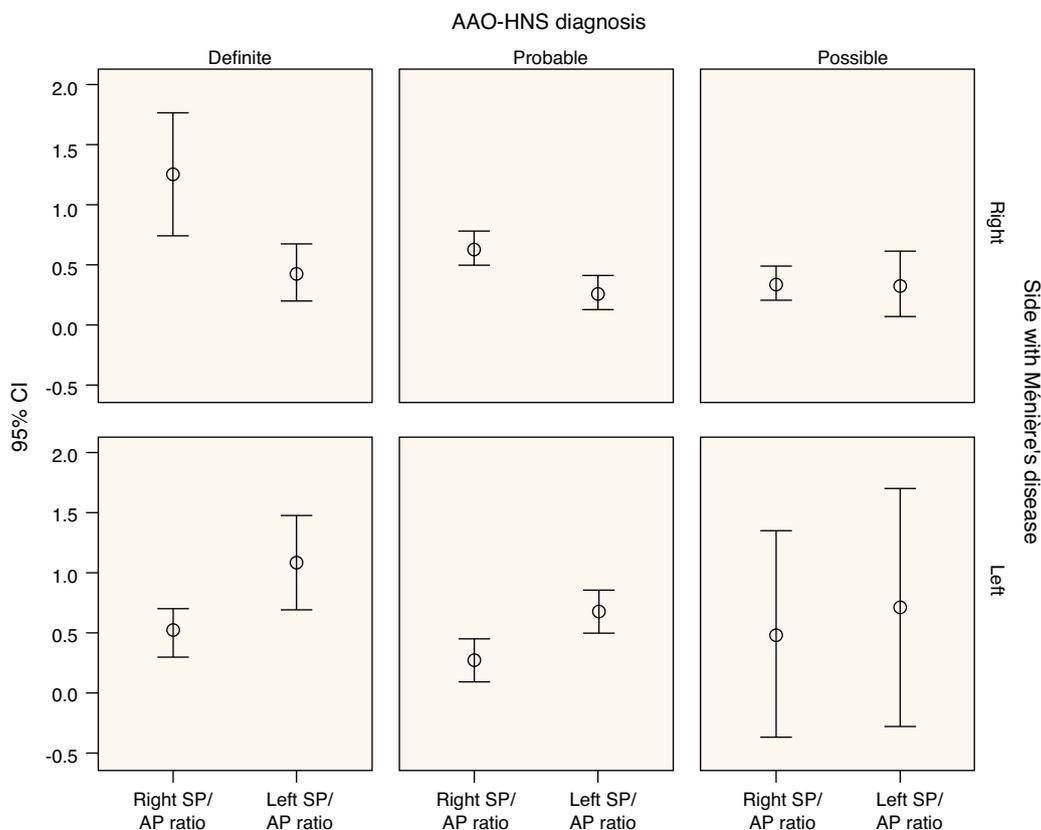


Figure 1 Error bars representing the SP/AP ratio according to the diagnostic stage (AAO-HNS, 1995) and the affected side.

Of the 100 patients included in the study sample, 85% met the electrophysiological criteria for Ménière's disease according to the ECoG parameters (SP/AP>0.5).

The percentages of altered ECoG according to diagnosis were 92%, 78% and 75% for definite, probable and possible Ménière's disease, respectively, as shown in Table 5.

When comparing the values of the SP/AP ratio obtained in the population of patients with definite Ménière's disease and the remaining categories together (probable and possible), the variation obtained was statistically significant. No statistically significant variations were found when comparing the 2 latter groups (probable and possible), since both values were very close.

When comparing the value of the SP/AP ratio of the affected side with the contralateral, healthy side, we observed highly significant variations ($P<.001$) in the category of definite Ménière's disease and significant in the case of probable Ménière's disease. Among those cases with possible Ménière's disease, the values were not statistically significant (Fig. 1).

We did not observe statistically significant variations when comparing the results of the SP/AP ratio in the patient sample divided by audiometric stage, although there was a tendency towards higher ratios among patients with greater hearing loss. The duration of the disease in months showed a high correlation with the SP/AP ratio, with a longer period of evolution corresponding to a higher value of this ratio (Figs. 2 and 3).

Similarly, the time elapsed since the last vertigo crisis until the ECoG showed a statistically significant inverse relationship, with a shorter time since the last episode corresponding to a higher SP/AP ratio (Figs. 4 and 5).

Lastly, we found no statistically significant relationships between the values obtained in vestibular tests and ECoG results. The study of rotatory tests parameters (gain, phase and symmetry in the harmonic sinusoidal test, and the time constant in the impulse test) did not reveal any statistically

Table 4 Mean Gain, Phase and Symmetry Values of the Population in the Sinusoidal Rotatory Test.

	0.16	0.32	0.64
Phase	14.04 ± 8.9	12.21 ± 11.7	18.1 ± 9.3
Gain	0.48 ± 3.2	0.53 ± 2.1	0.62 ± 2.2
Symmetry	11 ± 3.4	12 ± 3.2	31 ± 3

Table 5 Percentage of Altered ECoG and Value of the Corresponding SP/AP Ratio Based on the Diagnosis According to the AAO-HNS Criteria.

Diagnosis	Percentage of Altered ECoG (%)	SP/AP Ratio
Definite Ménière	92	1.02 ± 0.16
Probable Ménière	78	0.61 ± 0.06
Possible Ménière	75	0.53 ± 0.32
Normal group	20	0.33 ± 0.09

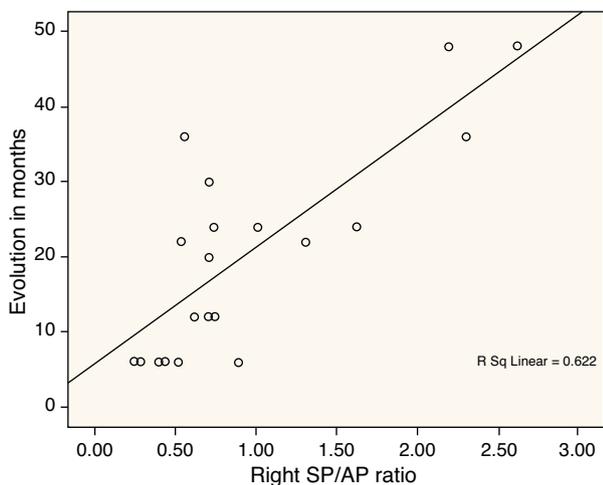


Figure 2 Linear regression graph establishing the relationship between the SP/AP ratio and the evolution time in months of Ménière's disease in the right ear.

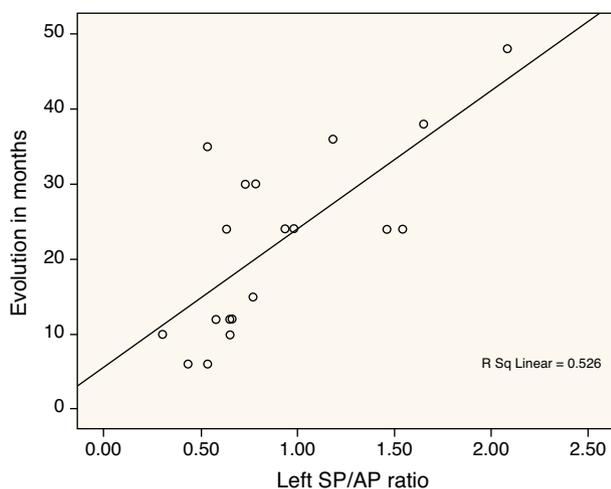


Figure 3 Linear regression graph establishing the relationship between the SP/AP ratio and the evolution time in months of Ménière's disease in the left ear.

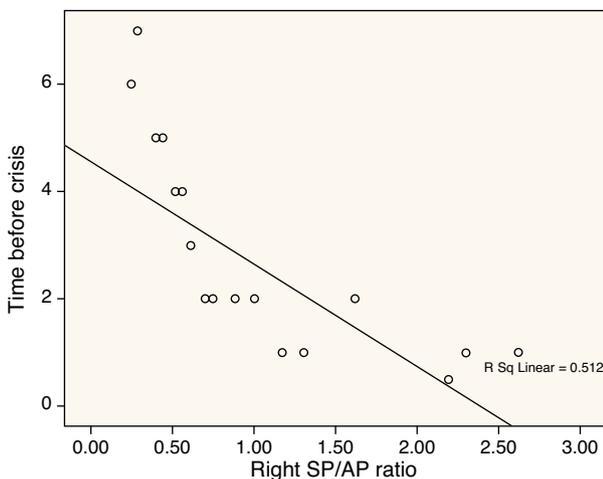


Figure 4 Regression graph between the time in months prior to the last crisis and the SP/AP ratio in patients with right Ménière's disease.

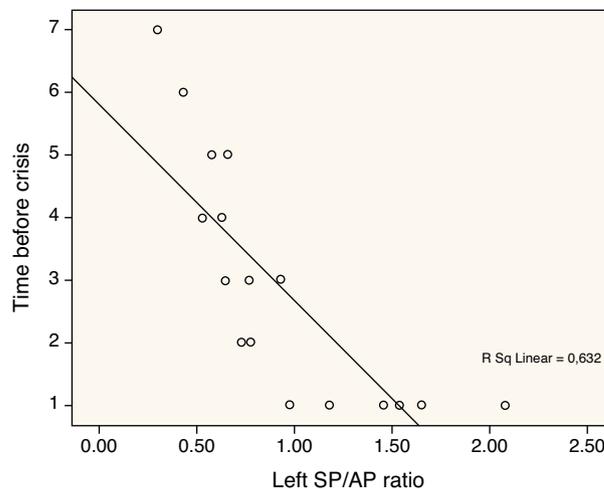


Figure 5 Regression graph between the time in months prior to the last crisis and the SP/AP ratio in patients with left Ménière's disease.

significant relationship with the value of the SP/AP ratio in our patient sample.

Discussion

This study demonstrates the presence of alterations in the extratympanic ECoG of patients with Ménière's disease, thus confirming its usefulness in the diagnosis of this condition.

Pappas et al.⁷ established the need for each centre to conduct the study on its own patient population, in order to obtain significant parameters and confidence levels.

This fact is particularly important with regard to obtaining figures for optimal sensitivity and specificity for the test, as this largely depends on the values of normality and the parametric range.

There are numerous publications reporting sensitivity and specificity values for ECoG.⁸ These works often describe the inherent difficulties of the test, given the wide dispersion of existing data.

Reviewing the various publications, it is possible to identify some variability in the SP/AP thresholds for the diagnosis of Ménière's disease between different authors. Ridenour et al.⁹ calculated an SP/PA ratio of 0.39 for males and 0.25 for females, whereas Sass⁸ established a unified ratio of 0.41. Pappas et al.⁷ believed that any result over 0.5 is suggestive of endolymphatic hydrops, whereas Iseli and Gibson¹⁰ established a significantly lower value of 0.33, thus modifying the specificity figures. Therefore, each laboratory must establish a threshold for the SP/AP ratio for the diagnosis of Ménière's disease and thus obtain figures for optimal sensitivity and specificity. Among our patient population and with our estimate of a required SP/AP ratio threshold greater than 0.5, we obtained a sensitivity of 85% (85 out of 100 patients obtained a value greater than 0.5) and a specificity of 80%.

These figures are similar to those obtained by other authors in various studies.¹¹ Nevertheless, despite obtaining objective data suggestive of the diagnosis of Ménière's disease, clinical presentation and evolution remain the gold

standard. Therefore, the sensitivity and specificity values of any diagnostic test for this syndrome will always be subject to variation depending on the study population, evolution time, medical treatment, etc.

In the present study there was a significant positive correlation between the duration of symptoms and ECoG findings. Although not all authors have found this statistical significance,^{11–13} our experience was similar to that of other authors^{14,15} in that patients with a longer evolution time presented higher SP/AP ratios. This was consistent with the observation that those patients in our study who presented clearer clinical criteria for the disease (definite Ménière's disease) also presented significantly higher SP/AP ratios than patients in the remaining stages (probable and possible Ménière's disease). Given the natural history of the disease and its initial clinical presentation, it is common for patients with a longer evolution to present a more complete clinical form, characteristic of the category of definite Ménière's disease. By contrast, the initial presentation form is usually not very evident,^{16–18} in which case physicians merely report a clinical suspicion (probable or possible Ménière's disease).

Similarly, our study population showed a trend towards statistical significance when comparing their auditory status with the SP/AP ratio. Although the statistical analysis showed no significance (coinciding with the experience of authors such as Chung et al.¹¹), it is likely that a larger sample would show a link between greater hearing losses and higher SP/AP ratios. It is also likely that the time variable in months from the last vertigo crisis before performing the ECoG could represent an interaction or confounding factor with other variables, such as the PTA, for example.

Given the pathophysiology of Ménière's disease, in which the damage on the membrane of Reissner becomes irreversible while hydrops persists,¹⁹ it is quite likely that this change is at least partly responsible for elevating the SP/AP ratio. This would partly explain the notable inverse relationship between the time elapsed since the last vertigo crisis prior to the ECoG and the SP/AP ratio. Since ECoG is an objective measurement of the degree of endolymphatic hydrops, a significant link between the proximity of the crisis and the parameters recorded is to be expected.

In fact, this finding was used by some authors against the test, arguing that ECoG would only reflect the hydropic nature of the disease during crises.²⁰ Successive publications have refuted these observations, noting a permanence of ECoG changes during the inter-crisis periods of the disease.^{11,12,14}

Although videonystagmography with caloric and rotational tests is currently considered to be the gold standard for the diagnosis of vestibular disorders, such as Ménière's disease,²¹ the parameters obtained from these tests have shown no significant correlation with the SP/AP ratio.

While it is true that caloric and rotational vestibular tests have known sensitivity and specificity values for the detection of peripheral vestibular involvement,²² this sensitivity becomes markedly decreased in the early stages of Ménière's disease, in which hydrops has not yet generated relevant lesions on the lateral semicircular canal. This fact has been widely reported in daily clinical practice, in which classical vestibular tests are often negative in the early stages of the disease.

The pathophysiological evolution of Ménière's disease eventually leads to involvement of the macules of the semicircular canals by endolymphatic hydrops in advanced stages. This is reflected in the classification by evolutionary stages by Shea,²³ in which conventional vestibular tests would be affected in stage IV. This fact explains the inability of these tests to observe vestibular damage in a significant proportion of patients with Ménière's disease. By contrast, ECoG is capable of initially detecting cochlear hydrops, since this is usually present from the initial phases of the disease.²⁴

Conclusions

- ECoG is a useful method in the diagnosis and assessment of Ménière's disease.
- It provides accurate information to assess the progress of the disease and there is a correlation with the diagnostic stage.
- ECoG helps to understand the pathophysiological phenomenon of endolymphatic hydrops in Ménière's disease.

Conflict of Interests

The authors have no conflict of interests to declare.

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