Objective: Bithermal caloric tests are among those most commonly used in vestibular function studies and require a properly systematized approach. Irrigation sequence varies between laboratories. Our objective is to study the effect of irrigation sequence on the percentage of vestibular paresis.

Material and method: We analysed 1214 records, 77.51 % cold to hot sequences (C-H) and the rest hot to cold (H-C). We considered results above 24 % of vestibular asymmetry to be pathological.

Results: In general, 33.36 % of the records were pathological. Groups compared showed that H-C sequence had more significant (P < .001) pathological results than C-H (46.52 % vs 29.54 %).

Conclusion: Irrigation sequence has a significant influence on the outcome of caloric tests to for the detection of vestibular paresis. More studies are needed to confirm the best irrigation sequence.

Key words: Videonystagmography. Caloric test. Irrigation sequence. Vestibular paresis.

INTRODUCTION

Videonystagmography (VNG) is a diagnostic technique allowing the study of the vestibulo-ocular reflex through the detection and measurement of eye movements. This technique has advantages over traditional electronystagmography (ENG) but requires appropriate systematization and specific working conditions.

One of the tests included in the battery of videonystagmographic studies is the bithermal caloric test, probably the most widely-accepted test used today for the study of vestibular function and considered to be the gold standard for the diagnosis of unilateral vestibular
hypofunction. Its greatest advantage is that it analyzes the response from each ear independently. Fitzgerald et al. systematized its performance and established the concepts of canal paresis (CP) and directional preponderance, while various committees in both the United States and the United Kingdom have subsequently drawn up recommendations for the test’s standardization. There are no guidelines in this sense in Spain and so the different centres measure different parameters, as well as using a variety of performance systems. For example, with regard to the concept of canal paresis, various Spanish authors have set different cut-off values in their articles and there is no consensus on the degree of asymmetry considered pathological. One recent article even raises the need to overcome the problems deriving from the direct application of Jongkees’s formula through the definition of gender-dependent normalcy thresholds for the slow-phase velocity values of the nystagmus with each irrigation.

Something similar happens with the irrigation sequence used. Although most authors report starting the test with cold water in each ear before going on to using hot water, we have seen Spanish articles that start with hot water in their stimulation sequence with hot water. Not to mention the presence of international references proposing the use of new irrigation strategies known as closed loop9,10 which are intended to reduce the time taken for conducting the test while achieving comparable results.

All of these considerations have led us to question whether the results obtained at different otoneurology laboratories applying separate methods and with different instruments are comparable with each other, so as to be able to reach a methodological standardization. What is more, we are doubtful as to whether the results are comparable within a single laboratory if any of the variables indicated were altered.

On the basis of these observations, the goal of our study is to evaluate whether the changes in how the bithermal caloric test is carried out lead to significant variations in the results with regard to canal paresis.

MATERIAL AND METHOD

We have analyzed the records of all the tests performed at our centre, a reference hospital with an allocated population of about 400,000 people, between March, 2005, and July, 2006. All the tests were carried out on patients with clinical signs of vertigo or dizziness. A total of 1214 tests were conducted, corresponding to 1099 patients.

We perform two different irrigation sequences. In the period between March, 2005, and March, 2006, all of the irrigations followed the sequence cold then hot (C-H), that is to say we started irrigations with the right ear at 30°C (RE30) followed by the left ear at 30°C (LE30), then the right ear at 44°C (RE44) and finally the left ear at 44°C (LE44). After April, 2006, we changed the irrigation sequence to hot then cold (RE44, LE44, RE30, LE30) in order to study possible differences in the results.

All of the tests were performed using Ulmer Synapsis equipment, a Hortmann water calorimeter and a Homoth air calorimeter. The irrigations involved 120 mL of water at 30°C and 44°C for 20 seconds (60 seconds in the case of air tests). In those cases were sufficiently good responses were not detected (7 cases; 0.58%), we changed the irrigation temperature by 2°C (28°C-46°C).

Variables

For all patients, we studied on the one hand age, gender, number of examination made, irrigation sequence, use of water or air, irrigation time and the person conducting the tests as independent variables and, on the other hand, the spontaneous nystagmus (SN) slow-phase velocity values, the response of both ears to hot and cold water, the sum of the responses in both ears (SPVS) and whether there was any deficit and its percentage.

To analyze the results, we basically used 2 variables: the percentage of responses with pathological deficits (%CP), that is to say those where the asymmetry between both ears is >24% (Balogh et al, 1990), known as canal paresis (CP); and the mean values for the sum of the angular velocities in the slow phase during the culmination period of the 4 irrigations (SPVS=RE44+LE44+RE30+LE30). We used this variable to analyze the overall response of both ears in connection with the intensity of the nystagmi recorded, in view of the different sequence changes.

Statistical Method

The statistical analysis of the data was performed with the SPSS 12.0 for Windows software programme. Following the first stage of the descriptive study with the calculation of means, standard deviations, maximums and minimums for the quantitative variables and the absolute and relative frequencies as well as the qualitative variables, the second stage analyzed the relations between the dependent variables (%CP, SPVS, and SN) and the independent variables (age, gender, nurse, irrigation sequence, and text number) using different statistical tests. Thus, to analyze the association between the qualitative variables, the Yates correction test was used for 2×2 tables with less than 25% of its cells with an expected frequency <5% and Fisher’s test where the preceding hypothesis was not true. The χ² test was used in the case of tables larger than 2×2. For the association between qualitative and quantitative variables, a logarithmic regression was performed when the dependent variable was dichotomous. Where the dependent variable was numerical and the independent variable categorical, a comparison of means was made using Student t test or ANOVA, depending on whether the variable had 2 or more categories, respectively. We set a significance threshold of P<.05.

RESULTS

During our study period, between March, 2005, and July, 2006 (16 months), we analyzed a total of 1214 records corresponding to 1099 patients referred for bithermal caloric
tests after complaining of vertigo; of these, 64.15% were women and the mean age was 51.78 years (Table 1).

In general, we obtained 405 records with canal paresis (CP), representing only 33.36% of the total records. In 56 cases the canal paresis was bilateral, in other words the sum of the mean slow-phase velocity in the 2 irrigations of the ear with the greatest response in these patients was <5°/s. Patients between 40 and 49 years of age presented a higher index of bilateral canal paresis (6.49%).

Males gave a somewhat greater %CP than females (35.76% vs 32%), with a somewhat lower mean (32.02°/s and 39.16°/s) in the sums of the maximum slow-phase angular velocities (SPVS).

Males also showed higher mean values for spontaneous nystagmus than females (0.72°/s and 0.68°/s).

The age group with the greatest deficits was that between 70 and 79 years of age (77 cases; 52.74%) (Figure 1). In turn, this same group, together with those over 79 years of age, presented higher than normal rates of spontaneous nystagmi (>2°/s; 8.90% and 10%, respectively). The presence of a large number of spontaneous nystagmi in patients reporting a recent vertigo crisis was grounds for the test to be repeated. In other cases, spontaneous nystagmus was assessed individually and, occasionally, it was later necessary to perform an imaging scan because of the characteristics of the nystagmus. In patients with spontaneous nystagmus and very high slow-phase velocity figures, we questioned the validity of the results of the caloric study.

Water was used in 94.98% of the tests, 77.51% in the sequence C-H and the remainder with the opposite sequence (H-C). In 7 cases, we changed the temperature by 2° (28°-46°) to try to achieve better responses. The H-C sequence showed a higher percentage of pathological deficits (46.52% and 29.54%) (Figure 2) and a lower SPVS.

Two nurses were involved in administering the tests. The first performed 60.46% (711) of them, mostly in the sequence C-H. The SPVS values were higher than those of the second nurse (37.76°/s and 29.98°/s) and the %CP values were lower (28.47% and 40.83%) (Figure 3). The mean values for spontaneous nystagmus (0.73°/s and 0.64°/s) were also higher, as were the percentages of patients with spontaneous nystagmus >2°/s (3.41% and 2.5%).

In 106 patients (9.65%), we performed more than one test (range 1–4). The mean time elapsed between tests was 5.69 months. Intervals of less than one week were used in 7.55% of the tests due to difficulties in interpreting the results correctly and mostly in patients with over 2 records (37.50%). SPVS was somewhat higher in the second test, before diminishing in the third and fourth tests. The %CP was lower in the second test (first test, 66.98%; second test, 44.34%).

**DISCUSSION**

We know that the values obtained in the bithermal caloric test may be affected by many variables, such as body temperature, the volume irrigated, the use of water or air for irrigation, etc. In order to avoid this variability, comparisons were made between the records obtained for each patient using Jongkees’s formula, allowing the presence or absence of asymmetries between the two ears to be established. There is no clear consensus in the literature regarding the values considered pathological. In our series we have used those published by Baloh et al, although other Spanish authors have set different normalcy thresholds (15% according to Pérez et al, 20% by Bartual, 25% for Amor et al).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Tests, n (%)</th>
<th>Patients, n (%)</th>
<th>Age, Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>439 (36.16%)</td>
<td>394 (35.85%)</td>
<td>50.83</td>
</tr>
<tr>
<td>Females</td>
<td>775 (63.84%)</td>
<td>705 (64.15%)</td>
<td>51.78</td>
</tr>
<tr>
<td>Total</td>
<td>1214 (100%)</td>
<td>1099 (100%)</td>
<td>51.44</td>
</tr>
</tbody>
</table>

![Figure 1. Distribution of patients by age and percentage of canal paresis, %CP.](image-url)
Theoretically, variations in the irrigation sequence should not affect the outcome of the test, as Jongkees’s formula compensates for the effect. Nonetheless, this is not so as we have found significant uncompensated differences. This has already been pointed to in other previous papers\textsuperscript{13,14} where mention is made of the effects caused by the order and the effects of temperature, and corrective factors have been proposed to avoid the over-diagnosis of hypofunction in a particular ear.\textsuperscript{13}

Our overall results show that we obtain pathological results in only 33.36\% of the cases, meaning that almost two thirds of the tests performed do not present pathological vestibular asymmetries. This result would speak in favour of the need to select better the patients in whom a bithermal caloric test is necessary. However, when we analyze the effect of the variation on the irrigation sequence, we see a statistically significant change ($P<.001$) in the percentages of normal tests. Thus, the sequence H-C detects 46.52\% as pathological versus 29.54\% with the sequence C-H. The sequence also changes the mean SPVS ($P=.004$) and we can see that the differences in the sequence H-C between the values recorded for irrigations with cold water are lower with respect to those with hot water, whereas they are accentuated in the sequence C-H (Table 2).

As for the person performing the test, we generally find that the tests conducted by the first nurse show higher mean SPVS and lower $\%CP$ with statistical significance ($P<.001$). Nonetheless, this finding is biased by the irrigation sequence, as the first nurse performed the sequence C-H in 96.87\% of cases while the second only did so in 47.92\%. Thus, when we compare the results of both nurses stratified by sequence, we can see that these differences disappear ($P=.276$).

Among the rest of the variables, we see that there are no differences between genders in terms of the percentage of patients with pathological asymmetries (35.76\% of males and 32\% of females) ($P=.203$), although there are in terms of the mean SPVS (32.02°/s in males and 36.19°/s in females; $P=.001$). Patients aged 60-69, together with those over 79 years of age, presented the highest intensity of responses (37.63 and 38.04 respectively) and, with respect to the deficit, the age group between 70 and 79 years of age presented a higher percentage of pathological vestibular hypofunctions (77 cases, 52.74\%), with a tendency of the percentage deficit to increase with age ($P<.001$).

![Figure 2](image-url)  
**Figure 2.** Percentage of pathological responses (canal paresis [$\%CP$]: asymmetries $>24\%$) by irrigation sequence.

![Table 2](table-url)  
**Table 2.** Mean Values for Slow-Phase Velocity in the Various Irrigations and by Irrigation Sequence*  

<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Mean SPV</th>
<th>Mean SPV C-H</th>
<th>Mean SPV H-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LE 30°C</td>
<td>12.55</td>
<td>12.84</td>
<td>11.54</td>
</tr>
<tr>
<td>RE 30°C</td>
<td>12.46</td>
<td>13.38</td>
<td>9.27</td>
</tr>
<tr>
<td>LE 44°C</td>
<td>5.56</td>
<td>5.44</td>
<td>6.00</td>
</tr>
<tr>
<td>RE 44°C</td>
<td>4.11</td>
<td>4.00</td>
<td>4.51</td>
</tr>
<tr>
<td>SPVS</td>
<td>34.68</td>
<td>35.66</td>
<td>31.33</td>
</tr>
</tbody>
</table>

*H-C indicates hot then cold sequence; C-H, cold then hot sequence; RE, right ear; LE, left ear; SPVS, mean of the slow-phase velocity sums of the 4 irrigations in $\circ/s$; SPV, slow-phase velocity of the nystagmus in $\circ/s$.

![Figure 3](image-url)  
**Figure 3.** Percentage of pathological responses (canal paresis [$\%CP$]: asymmetries $>24\%$) between the different nurses and stratified by irrigation sequence. H-C indicates hot then cold sequence; C-H, cold then hot sequence.
Finally, we know that the bithermal caloric test provides quantitative information on the degree of the deficit at a particular moment. This is sometimes used to study the evolution of the asymmetry over time and the onset of compensation phenomena. In our series we observed that %CP decreased significantly at the second measurement in comparison with the first (first test, 66.98%; second test, 44.34%), whereas there were no differences in the other variables.

All of the above allows us to state that the changes in the conditions for conducting the bithermal caloric test, specifically the irrigation sequence, bring about changes in the percentage of pathological results; however, in order to determine which sequence is better, it is necessary to carry out studies comparing the results with respect to a control group.

The irrigation sequence significantly changes the ability of the bithermal caloric test to show pathological asymmetries and the sequence H-C shows a higher percentage of deficit. It also changes the mean sum of the slow-phase velocity in the 4 irrigations, the general response of both ears in other words, and it is possible to see a reduction in the differences between the responses with hot and cold water in the H-C sequence. In our setting, we have not found differences in terms of the person conducting the test.

The group of patients aged 70-79 presented a higher percentage of pathological vestibular hypofunctions with a tendency of the percentage of tests with deficit to increase with age.

In patients given a second follow-up test, we generally noted a reduction in the asymmetry at the second measurement.

Therefore, we conclude that the changes in the methodology for the bithermal caloric test imply statistically significant changes in the results, making it necessary to systematize this test. Further studies are necessary to establish which is the most appropriate way to conduct the test in our setting.

REFERENCES