Research Article / Araştırma Makalesi

Evaluation of Suppression Head Impulse Paradigm (SHIMP) and the Video Head Impulse Test (vHIT) in Patients with Meniere's disease with Proven Vestibular and Auditory Loss

Kanıtlanmış Vestibüler ve İşitme Kaybı olan Meniere Hastalarında Supresyon Baş Savurma Paradigması (SHIMP) ve Video Baş Savurma Testinin (vHIT)

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Abstract: This study aimed to examine the results of the video head impulse test (vHIT), and suppression head impulse paradigm (SHIMP) in adult diagnosed with definite Meniere's disease (MD). This study was conducted with 20 patients aged 18-45 years with canal paresis and sensorineural type hearing loss in symptomatic ears, who were diagnosed with unilateral definite MD. The subjects were assessed with conventional audiometry (0.125–8 kHz), the bithermal binaural air caloric test, vHIT, and SHIMP. The mean SHIMP vestibulo-ocular reflex (S-VOR) gain of the MD side was 0.69, and that of the healthy side was 0.77. The S-VOR gain values were statistically lower than the mean vHIT VOR gain (V-VOR) values on both sides ($p<0.001$). There was no significant difference between the MD and healthy sides in terms of the anti-compensatory saccades (ACSs) latency and amplitude and S-VOR gain ($p>0.05$). In the MD group, the vHIT results were abnormal in 35% (7/20 ears) of the ears, and the SHIMP results were abnormal in 50% (10/20 ears). On the healthy side, the vHIT results were abnormal in 10% (2/20 ears) of the ears, and the SHIMP results were abnormal in 35% (7/20 ears). In this study, the V-VOR and S-VOR gains, vHIT saccades, SHIMP saccade latency, and SHIMP saccade amplitude were not found to be beneficial parameters in differentiating affected and healthy ears in the patients with MD. In other words, contrary to expectations, vHIT and SHIMP tests were not sufficient to detect pathological involvement in Meniere's disease.
Keywords: Meniere's Disease, Auditory Loss, Vestibular Loss, Suppression Head Impulse Paradigm, Video Head Impulse Test.

Özet: Bu çalışmada, kesin Meniere hastalığı (MH) tanısı alan erişkinlerde video baş savurma testi (vHIT) ve supresyon baş savurma paradigması (SHIMP) sonuçlarının incelenmesi amaçlandı. Bu çalışma, tek taraflı kesin MH tanısı almış, semptomatik kulaklarında kanal parezi ve sensörinöral tip işitme kaybı olan 18-45 yaş arası 20 hasta ile yapıldı. Bireyler, geleneksel odyometri (0,125–8 kHz), bitermal binaural hava kalorik testi, vHIT ve SHIMP ile değerlendirildi. MH olan tarafın ortalama SHIMP vestibülo-oküler refleks (S-VOR) kazancı 0,69, sağlıklı tarafınki ise 0,77 idi. S-VOR kazanç değerleri her iki tarafta da ortalama vHIT VOR kazanç (V-VOR) değerlerinden istatistiksel olarak düşüktü ($p<0,001$). Anti-kompansatuar sakkad (AKS) latansı ve genliği ile S-VOR kazancı açısından MH olan ve sağlıklı taraf arasında anlamlı bir fark yoktu ($p>0.05$). MH olan kulakların; vHIT sonuçları %35'inde (7/20 kulak), SHIMP sonuçları ise %50'sinde (10/20 kulak) anormaldi. Sağlıklı tarafta ise kulakların %10'unda (2/20 kulak) vHIT sonuçları ve %35'inde (7/20 kulak) SHIMP sonuçları anormaldi. Bu çalışmada sonuç olarak V-VOR ve S-VOR kazançları, vHIT sakkadları, SHIMP sakkad latansı ve SHIMP sakkad amplitüdünün Meniere hastalarında etkilenen ve sağlıklı kulakları ayırt etmede faydalı parametreler olmadığı bulunmuştur. Yani beklenenin aksine, Meniere hastalığı'nda patolojik tutulumu tespit etmek için vHIT ve SHIMP testleri yeterli değildi.
Anahtar Kelimeler: Meniere Hastalığı, İşitsel Kayıp, Vestibüler Kayıp, Supresyon Baş Savurma Paradigması, Video Baş Savurma Testi.

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1. Introduction

Meniere's disease (MD) is a chronic inner ear disease that frequently affects the semicircular canals (SSC) (1-3). Until recently, caloric test was the most frequently used method to detect involvement of SSCs in these patients. However, the caloric test evaluates the vestibulo-ocular reflex (VOR) showing SSC function in a low frequency range (0.002-0.004 Hz), which allows for the assessment of only the horizontal SSC (2). Also, the difficulties in the application of the caloric test are well known. Easy to use vestibular tests are needed to assess semicircular canal function in MD.

The video-head impulse test (vHIT) can be used to evaluate each SSC separately in MD (4,5). Unlike the caloric test, vHIT involves high-frequency stimulation (2.5-7 Hz), and therefore it can assess head movements similar to daily life. However, there are inconsistent results regarding the use of vHIT in MD (6-8). Recently, the suppression head impulse paradigm (SHIMP) test has been started to be used to reveal the affected peripheral vestibular system function (9-10). In this test, the same steps are followed as in vHIT. The most important difference between the two tests is that in vHIT, the individual is expected to focus on the target fixed on the wall throughout the test, while in the SHIMP test, the individual is expected to focus on and follow the red laser light (moving target) shifting on the wall depending on head movement. In the SHIMP protocol, due to horizontal VOR, individuals with intact vestibular function create a large anti-compensatory saccade (ACS) (SHIMP saccade) to capture the target at the end of head movement. ACSs are not observed in the SHIMP test in patients with the loss of vestibular function because the eyes move with the head. Therefore, the absence of ACSs in the SHIMP test is considered an indicator of vestibular disorders (11-12).

In clinical practice, vestibular tests are utilized for the diagnosis of MD, but which tests should be included in the oto-neurological test battery remains controversial. The SHIMP test is a fairly new evaluation method, and we did not find any study in the literature evaluating patients with MD using this method. In addition, although there are studies on vHIT investigating vestibular involvement in MD, there are only limited studies conducted with individuals that have proven both auditory and vestibular loss (13). Therefore, this study aimed to examine the results of the vHIT and SHIMP tests in adult patients diagnosed with unilateral definite MD, who had proven loss of peripheral vestibular and auditory function on the affected side.

2. Materials and Metods

The study included 20 adult subjects aged 18-45 years with canal paresis and sensorineural type hearing loss in symptomatic ears (20 symptomatic, 20 asymptomatic/40 ears), who had been diagnosed with unilateral definite MD according to the diagnostic criteria of Barany Society at least one year earlier. The ears with MD (symptomatic ears) were considered as the study group and healthy ears (asymptomatic ears) as the control group. Patients receiving active medical treatment, those that had undergone ear surgery and/or intratympanic treatment, those with a history of eye surgery within the last six months, those with neurological, psychiatric, cardiological, systemic, or metabolic diseases (such as diabetes mellitus), those using ototoxic drugs (loop diuretics, etc.), and those with cervical problems (flattening in the neck and herniation), an air-bone gap in the audiogram–were excluded from the study. From October 2020 to April 2022, we prospectively examined patients with MD, who presented to the otolaryngology department of our tertiary hospital. Written informed consent was obtained from all the participants, and the study was approved by from the local ethics committee (approval number: 38).

Hearing loss was confirmed in all patients by conventional audiometry (the air conduction hearing thresholds at 0.25-8.0 kHz and bone conduction thresholds at 0.5-4.0 kHz were determined). The pure tone average (PTA) values of air conduction thresholds (0.5, 1 and

2 kHz) were calculated. Diagnosis of a peripheral vestibular deficit was confirmed in all patients by bithermal caloric testing with air irrigation at 25°C and 50°C and the slow phase velocity (SPV) of nystagmus was compared. When SPV was ≥25% in one ear, unilateral weakness/canal paresis was considered (14).

vHIT was applied using computer software, with the patients wearing special test glasses equipped with a video camera and mounted mirror (ICS Impulse system; GN Otometrics, Taastrup, Denmark). This clear mirror reflects the image of the eye to the camera, and a small sensor in the glasses measures head movement. During the test, the subjects were asked to fix their attention on the target that was attached to the wall while sitting one meter away from it. The head was moved to the right and left at uncertain times by the clinician (head impulses), bilateral horizontal SSC stimulation was provided, and VOR responses were obtained. An average of 20 pushing movements was performed for each direction. The patients' VOR gains and saccades were recorded. If the peripheral vestibular system is intact and the VOR is functioning normally, almost no corrective saccade is observed in the eyes during vHIT, since the subject can maintain fixation on the target and wall during head movement (because eyes do not move away from the target). However, in subjects with vestibular dysfunction, VOR loses its coherence with head movement, and the eyes move with the head and deviate from the target. Therefore, to recapture the target, the eye must make a corrective saccade (compensatory saccade). If the VOR gain was not within 0.8-1.2 for the horizontal canals (15) or if there were covert and/or overt catch-up saccades, this was accepted as an abnormal vHIT response. In the following stage, the SHIMP test was applied to the individuals using the same device as in vHIT. The application procedures of SHIMP and vHIT are the same, but one important difference is that for the vHIT test, the subject is expected to focus on the target fixed on the wall throughout the test, while in the SHIMP test, the individual is asked to focus on and follow the red laser light displayed on the wall by moving their head.

As a result of the SHIMP test, the average of the VOR gain of both horizontal SCCs and the amplitude and latency values of the resulting ACS traces were calculated (12). The arithmetic mean values of saccade latency and amplitude were calculated as the sum of saccade latency and amplitude values divided by the number of trials. If the VOR gain was not within 0.8-1.2 for the horizontal canals or if there were not ACSs, this was accepted as an abnormal SHIMP response. The aforementioned parameters were compared between the MD and control ears.

Statistical Analysis

Data analysis was performed using SPSS v. 21.0. The descriptive statistics of quantitative variables were shown as mean ± standard deviation and median (Q1-Q3), while qualitative variables were presented as count and percentages. The normality of quantitative variables was evaluated with the Shapiro-Wilk test. The paired-samples t-test was used to compare the MD and control groups in terms of normally distributed variables. For non-normal distributed variables, the comparisons were performed with the Wilcoxon test. The Pearson and Spearman correlation analyses were used to assess the relationship between quantitative variables for the normal and non-normal distributed data, respectively. P values of less than 0.05 were considered significant.

3. Results

The study included 20 adults (40 ears) (mean age 41.7 ± 9.8 years). In the affected side, PTA were significantly higher ($p < 0.001$), and canal paresis was present (mean unilateral weakness: 54%) in all the ears in this group (n = 20). There was no hearing loss or canal paresis in the healthy ears. None of the affected ears showed an air-bone gap during the audiometric examination.

We measured horizontal vHIT and horizontal SHIMP in the patients diagnosed with MD. The mean vHIT VOR gain (V-VOR) of the MD side was 0.96, and that of the healthy side was 1.01. The mean SHIMP VOR gain (S-VOR) of the MD side was 0.69, and that of

the healthy side was 0.77. The S-VOR gain values were statistically lower than the V-VOR gain values on both sides ($p < 0.001$). There was no significant difference in the VOR gain between the two groups of ears according to both test methods ($p > 0.05$). Considering both VOR gain and saccades, in the MD group, the vHIT results were abnormal in 35% (7/20 ears) of the ears, and the SHIMP results were abnormal in 50% (10/20 ears). In the healthy control group, the vHIT results were abnormal in 10% (2/20 ears) of the ears, and the SHIMP results were abnormal in 35% (7/20 ears). There was no significant difference between the MD and control groups of ears in relation the ACS latency and amplitude values ($p > 0.05$). The statistical analyses of the PTA, V-VOR, S-VOR, and SHIMP saccade latency and amplitude values of the affected and healthy sides are given in Table 1, and the box plots of V-VOR and S-VOR are presented in Figure 1.

Table 1. Comparison of affected and healthy ears according to quantitative variables

	Affected side (20 ears)		**healthy side (20 ears)**		**p**
PTA (dB HL)	40.35±14.36	39(30-49)	9.45±4.61	10(5-14.5)	**<0.001**[a]
V-VOR	0.96±0.18	0.98(0.9-1.07)	1.01±0.11	1.03(0.92-1.08)	0.334[b]
S-VOR	0.69±0.24	0.78(0.5-0.89)	0.77±0.21	0.83(0.59-0.97)	0.103[a]
SHIMP saccade latency (ms)	186.49±52.66	179.6(154.55-210.15)	183.36±49.99	166.15(149.5-214.65)	0.502[b]
SHIMP saccade amplitude (^{0}/s)	259.67±48.63	254.56(219.1-292)	271.22±54.94	275.3(235.5-308.4)	0.108[b]

[a]*paired-samples t-test;* [b]*Wilcoxon test; PTA, pure tone average; VOR, vestibulo-ocular reflex; V-VOR, video-head impulse VOR gain; S-VOR, suppression head impulse paradigm VOR gain*

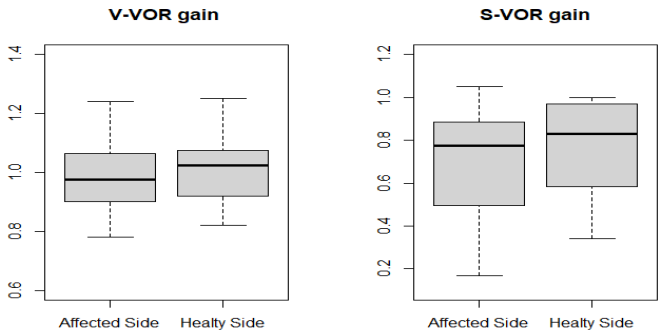

Figure 1. Box plots of the vestibulo-ocular reflex gain of the affected and healthy ears according to the video-head impulse test (V-VOR) and the suppression head Impulse paradigm test (S-VOR)

A significant and moderate positive correlation was found between unilateral weakness (UW) rate of the affected side and PTA of the same side ($r = 0.471$, $P = 0.036$). There was no correlation between UW and the remaining variables. The findings of the relationship between the UW rate of the affected side and the PTA, V-VOR, S-VOR,

SHIMP saccade latency, and SHIMP saccade amplitude values are shown in Table 2, and the box plots of the comparison of the SHIMP saccade latency and amplitude values are given in Figure. 2.

Table 2. Correlation coefficients and p values between the unilateral weakness rate on the affected side and the investigated variables

		PTA	V-VOR	S-VOR	SHIMP saccade latency	SHIMP saccade amplitude
Unilateral weakness (%)	r	**0.471**[a]	0.365[b]	0.225[a]	0.133[b]	0.329[a]
	p	0.036	0.114	0.339	0.575	0.156

[a]*Pearson's test;* [b]*Spearman's test; PTA, pure tone average; VOR, vestibulo-ocular reflex; V-VOR, video-head impulse VOR gain; S-VOR, suppression head impulse paradigm VOR gain*

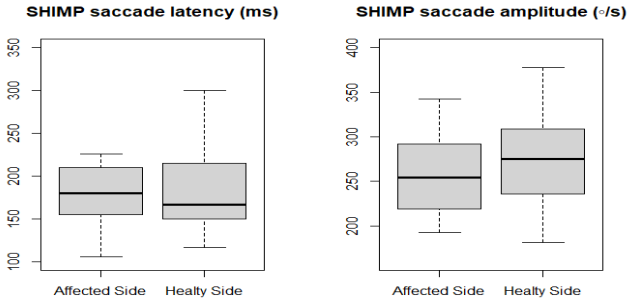

Figure 2. Box plots of the comparison of the affected and healthy sides in terms of the suppression head impulse paradigm (SHIMP) saccade latency and saccade amplitude values

The mean disease duration of the patients with MD was 36.7 months (range, 6–96 months). There was no significant relationship between disease duration and the results of the SHIMP test. The analysis results of the relationship between disease duration and S-VOR and SHIMP saccade latency and amplitude are given in Table 3.

Table 3. Correlation coefficients and p values showing the relationship between disease duration and SHIMP test results in the affected ears

		S-VOR	SHIMP saccade latency	SHIMP saccade amplitude
Disease duration (month)	r	0.043[a]	-0.177[b]	-0.102[a]
	p	0.858	0.455	0.668

[a]*Pearson's test;* [b]*Spearman's test; VOR, vestibulo-ocular reflex; SHIMP, suppression head impulse paradigm; S-VOR, SHIMP VOR gain*

Table 4 presents the findings of the relationship between PTA and V-VOR, S-VOR, SHIMP saccade latency, and SHIMP saccade amplitude in the affected side. No significant relationship was found between PTA and these variables.

Table 4. Correlation coefficients and p values showing the relationship between the degree of hearing loss and vHIT and SHIMP test results in the affected ears

		V-VOR	S-VOR	SHIMP saccade latency	SHIMP saccade amplitude
PTA	r	0.045[b]	-0.268[a]	0.147[b]	0.104[a]
	p	0.849	0.252	0.536	0.664

[a]Pearson's test; [b]Spearman's test; PTA, pure tone average; VOR, vestibulo-ocular reflex; V-VOR, video-head impulse VOR gain; S-VOR, suppression head impulse paradigm VOR gain

4. Discussion

In current study, the VOR gain and saccades obtained using the vHIT and SHIMP tests were evaluated in the patients diagnosed with MD, who had proven vestibular and auditory loss. In the MD ears, there was a significant and moderate positive correlation between the UW ratio and PTA (r = 0.471, P = 0.036). As hearing loss increased on the affected side, vestibular loss also increased. Considering only the VOR gain, in the MD group, pathological results were obtained for V-VOR (2/20) in two ears and S-VOR in 10 (10/20) ears. On the healthy side, V-VOR was within the normal range in all 20 ears and S-VOR was within the normal range in 13 (13/20). According to the VOR gain, the sensitivity of both tests and the specificity of SHIMP were very low. In other words, the VOR gain of each test alone was not sufficient in distinguishing the affected ears from the healthy ears among the individuals with MD; therefore, the VOR gain was considered to be a non-practical parameter. Although the mean VOR gains of the individuals were lower on the MD side, this difference was not significant. MacDougall et al. (11) also reported significantly lower S-VOR values than V-VOR values in individuals with bilateral vestibulopathy and healthy control groups. It has been suggested that the VOR gain obtained with SHIMP being significantly lower than the V-VOR gain can be explained by different VOR inhibition strategies. However, it is also stated that such strategies have not been conclusively proven (16). Consistent with the literature, we determined that the S-VOR gain values of the patients with MD were statistically lower than their V-VOR gain values when the same side was evaluated ($p < 0.001$).

In our study, ACSs were obtained using the SHIMP test in both the affected and healthy ears. There was no significant difference between the ears in the latency and amplitude values of ACSs ($p > 0, 05$). There was no significant relationship between disease duration and the SHIMP test parameters. On the other hand, using the vHIT test, pathological saccades were found in seven ears on the MD side and two ears on the healthy side. In the affected ears, no significant relationship was observed between the amount of hearing loss (PTA) and the V-VOR, S-VOR, and SHIMP saccade latency and amplitude values. There was also no significant relationship between the amount of vestibular loss (UW) and the aforementioned parameters on the affected side. In brief, our results showed that although vestibular (using the gold standard caloric test) and auditory loss was proven on the affected side, only 35% of the definitive MD ears had abnormal vHIT results, and 50% had abnormal SHIMP results. On the other hand, 10% of healthy ears had abnormal vHIT and 35% had abnormal SHIMP test results. Similar to our study, Bladow et al. obtained abnormal head impulse test findings in only 40% of patients with abnormal findings in the caloric test [8].

There are also other studies that reported normal vHIT results in patients with a definite MD diagnosis (7,17). According to our study, even in the presence of auditory and vestibular loss, vHIT does not seem to be sufficient in the diagnosis of patients with MD.

To the best of our knowledge, there is no study in the literature that directly evaluated patients with MD using the SHIMP test,

which has recently been shown to reveal weaknesses in peripheral vestibular system function. Although there is a study conducted with a heterogeneous patient group including MD cases, the results reported were not specific for MD (18). Since SHIMP is a new test, there are also only few studies in the literature evaluating patient groups other than MD. Since the literature does not contain the SHIMP test results of patients with MD, we were not able to compare our study results. However, the S-VOR gain and ACS findings of our study showed that the SHIMP test was not clinically useful in the MD patient group, similar to vHIT. In a study evaluating patients with unilateral acute vestibular neuritis, Park et al. (19) reported 95% sensitivity and 91% specificity for V-VOR and S-VOR, respectively. The reason for the higher sensitivity and specificity of the SHIMP test in these patients can be related to the different pathophysiologies of vestibular neuritis and MD. We applied the SHIMP test in the inactive/chronic period of MD. However, it is not possible to perform these tests in the acute periods of the disease (due to the reduced quality of life and patients' often presenting to the emergency department rather than otolaryngology clinics). Our study is the first to include cases with proven vestibular-auditory loss in a homogeneous group of inactive MD cases. In this study, the V-VOR and S-VOR gains, vHIT saccade, SHIMP saccade latency, and SHIMP saccade amplitude were not found to be beneficial parameters in differentiating between the affected and healthy ears in the patients with MD. In other words, vHIT and SHIMP were not sufficient in the diagnosis of MD. The caloric test is still the most reliable method to prove semicircular canal involvement in Menier's disease.

The main limitation of our study is that tests are performed during the chronic phase of MD (due to difficulties in evaluation in the acute phase). In future studies, different results can be obtain if evaluations are made in the acute phase of the disease in a larger patient population.

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Ethic

Ethics Committee Approval: The study was approved by Eskişehir Osmangazi University Noninterventional Clinical Research Ethical Committee (Decision no: 38, Date: 29.09.2020).
Informed Consent: The authors declared that it was not considered necessary to get consent from the patients because the study was a retrospective data analysis.
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