ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.24179/kbbbbc.2020-78320

What Can We Predict with Video Head Impulse Test in Unilateral Vestibular Disorders?

Tek Taraflı Vestibüler Hastalıklarda Video Head Impulse Test ile Neleri Öngörebiliriz?

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ABSTRACT Objective: We applied video head impulse test (vHIT) to all patients before audio-vestibular test battery and aimed to investigate the vestibular problems which can be predicted by vHIT in various vestibular disorders. **Material and Methods:** The data of 88 patients diagnosed with various unilateral vestibular disorders were examined in this prospective study. Ear-nose-throat (ENT) examination, vHIT, pure tone audiometry, cervical vestibular evoked myogenic potential and videonystagmography including caloric test were applied to all patients respectively. **Results:** Abnormal vHIT (horizontal and/or vertical canals) was determined in 81.8% of the patients with unilateral vestibular disorder. Abnormal horizontal canal vHIT was seen in 74.5% of the patients with canal paresis and in 46.3% of the patients without canal paresis in caloric irrigation ($p<0.05$). Abnormal posterior vHIT was determined in 44.7% of the patients with canal paresis and in 65.9% of the patients without canal paresis in caloric irrigation ($p<0.05$). Abnormal vHIT was found in all of 8 patients with BPPV included the study Comorbid disease and/or vestibular hypofunction was also found in all of 8 patients after all vestibular tests. Abnormal vHIT (horizontal and/or vertical canals) was found in the majority of patients (29/31) with Meniere's disease. **Conclusion:** The results showed that unilateral vestibular hypofunction could be determined largely by vHIT. The localization of pathology may be estimated by performing both lateral and vertical vHIT. Performing vHIT before provocative maneuvers might be useful in predicting a comorbid disease and treatment success in patients with BPPV.

Keywords: Head impulse test; caloric test; vertigo; vestibular diseases

ÖZET Amaç: Bu çalışmada, çeşitli vestibüler hastalıklarda odyovestibüler test bataryası öncesinde video head impulse test (vHIT) yaparak vHIT ile öngörülebilen vestibüler patolojileri araştırmayı amaçladık. **Gereç ve Yöntemler:** Bu prospektif çalışmada çeşitli tek taraflı vestibüler hastalık tanısı alan 88 hastanın verileri incelendi. Tüm hastalara sırasıyla kulak burun boğaz muayenesi ve vHIT, saf ses odyometrisi, servikal vestibüler uyarılmış miyojenik potansiyeller (cVEMP), kalorik test dahil videonistagmografi testleri yapıldı. **Bulgular:** Hastaların %81,8'inde anormal vHIT (horizontal ve/veya vertikal kanal teslerinde) bulguları vardı. Kalorik testte kanal parezisi bulunan hastaların %74.5'inde, kanal parezisi bulunmayan hastaların ise %46,3'ünde anormal horizontal kanal vHIT bulguları saptandı ($p<0,05$). Kalorik testte kanal parezisi bulunan hastaların %44,7'sinde, kanal parezisi bulunmayan hastaların ise %65,9'unda anormal posterior kanal vHIT bulguları saptandı ($p<0,05$). Çalışmaya dahil edilen 8 BPPV hastasının tümünde anormal vHIT bulguları görüldü. Bu 8 hastanın tümünde tüm odyovestibüler testler tamamlandıktan sonra etkilenen tarafta komorbid hastalık ve/veya vestibüler hipofonksiyon doğrulandı. Meniere hastalarının çoğunda (29/31) anormal vHIT bulguları (horizontal ve/veya vertikal kanal testlerinde) vardı. **Sonuç:** Bulgular, tek taraflı vestibüler hipofonksiyonun çoğu hastada vHIT ile belirlenebileceğini göstermektedir. Patolojinin lokalizasyonu hem horizontal, hem de vertikal vHIT yapılarak tahmin edilebilir. BPPV hastalarında provokotif manevra öncesinde vHIT uygulanması komorbid vestibüler hastalıkları ve tedavi başarısını öngörmede faydalı olabilir.

Anahtar Kelimeler: Head impulse test; kalorik test; vertigo; vestibüler hastalıklar

Video head impulse test (vHIT) is commonly used for the evaluation of vestibular system disorders because it can be performed easily in a short period of time. However, there is no diagnostic value to vHIT alone. Patient history and examination findings contribute the most important information in the diagnosis of vestibular disorders and in some pathologies such as benign paroxysmal positional vertigo (BPPV) and Meniere's disease, a correct diagnosis can generally be made with a limited number of laboratory

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Peer review under responsibility of Journal of Ear Nose Throat and Head Neck Surgery.

Received: 29 Jul 2020 ***Received in revised form:*** 25 Aug 2020 ***Accepted:*** 25 Sep 2020 ***Available online:*** 23 Dec 2020

tests. Nevertheless, in some cases the application of the whole vestibular test battery is necessary for a correct diagnosis, as each test is of assistance in evaluating different parts of the vestibular system and comorbid vestibular pathologies can be seen in at least some of the patients.

Both the lateral semicircular canal vHIT and the caloric test measure the VOR arc originating from the lateral semicircular canal ampulla.[1] Many studies have compared the lateral semicircular canal head impulse test (HIT) and caloric tests. Some authors have stated that HIT is not an alternative to the caloric test as they stimulate different frequencies of VOR.[1-3] Many authors have reported that the caloric test is more sensitive than vHIT in determining unilateral vestibular insufficiency in various vestibular diseases.[3-6] According to some authors, the HIT shows low sensitivity in the identification of mild and moderate vestibular hypofunction and high sensitivity in severe vestibular hypofunction.[7-10] However, vHIT also have some advantages. This test is non-invasive and can be performed in a short period of time. Additionally, all semicircular canal functions might be evaluated by performing both lateral and vertical vHIT. Therefore, performing vHIT first may offer an additional advantage. If a pathological finding occurs in vHIT, this finding will help in the selection of the test or tests of the next step.We applied video head impulse test (vHIT) to all patients before audio-vestibular test battery and aimed to investigate the vestibular problems which can be predicted by vHIT in various vestibular disorders.

MATERIAL AND METHODS

This prospective study was conducted in the Neurotology Clinic of the Ear, nose and throat (ENT) Department. Patients admitted to the Neurotology Clinic with various vestibular symptoms (vertigo, dizziness, spinning sensation, lightheadedness, floating sensation, imbalance) between 2015 and 2016, and who agreed to participate in the study were enrolled. This study was approved by the University Institutional Review Board and Ethics Committee (Project no: KA15/284; 26.10.2015) and was supported by the University Research Fund. It was conformed the ethical norms and standarts in the Declaration of Helsinki and informed consent was obtained from all participants.

ENTexamination, vHIT, pure tone audiometry, cervical vestibular evoked myogenic potential (cVEMP) and videonystagmography (VNG) including the bithermal caloric test were applied to all patients, respectively. The audio-vestibular tests were performed by two experienced audiology technicians and evaluated by a researcher who was blinded to the vHIT results. vHIT was evaluated by another researcher who was blinded to the audiovestibular test results. The data of patients diagnosed with benign paroxysmal positional vertigo (BPPV), Meniere's disease (MD), vestibular neuritis (VN), vestibular migraine (VM), vestibular schwannoma (VS) and chronic vestibulopathy (CV) were examined. All patients enrolled in the study had unilateral disease. Any patients with bilateral vestibular disease, central nervous system disorders, chronic otitis media, conductive hearing loss and who couldn't complete the all tests were excluded from the study. Patients with neck disorders were also excluded from the study because of the handicap in performing vHIT. Menière's disease and BPPV were diagnosed according to the clinical criteria defined by the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS);[11-12] vestibular migraine was diagnosed according to the clinical criteria defined by the Committee for the Classification of Vestibular Disorders of the Bárány Society and the Migraine Classification Subcommittee of the International Headache Society (IHS);[13] vestibular neuritis was diagnosed according to history, audiovestibular test results and on the exclusion of other peripheral vestibular disorders; vestibular schwannoma was diagnosed according to magnetic resonance imaging (MRI) and audiovestibular test results. Patients with unilateral vestibular loss not compatible with any vestibular disease were evaluated as chronic vestibulopathy.

VIDEO HEAD IMPULSE TEST

The vHIT was performed using the Otosuite Vestibular computer program and goggles with a camera attached (GN Otometrics, Taastrup, Denmark). The head was leant forward 30° and was then thrust right and left randomly in the horizontal plane (head velocity ~100-250°/sec) to induce lateral semicircular canals. The head was thrust forward and backward randomly in the sagittal plane (head velocity ~50-

250°/sec) to induce the vertical semicircular canals (LARP and RALP). Twenty impulses given true were accepted for the evaluation of each canal. The normal range of vestibulo-ocular reflex (VOR) gain for lateral and vertical vHIT were accepted as 0.8-1.2 and 0.7-1.2, respectively. Saccade with an amplitude higher than peak head velocity was accepted as pathological saccade. A saccade beginning before the end of the head movement was considered as a covert saccade while a saccade beginning after head movement termination was considered as an overt saccade. In some patients, the saccade amplitude was lower than the peak head velocity in vHIT. If the saccade was compatible with the affected ear determined by pure tone audiometry, post-head shaking and caloric test, it was also evaluated as abnormal saccade.

BITHERMAL CALORIC TEST

The caloric test was performed using a binocular video oculography system. Caloric irrigation was performed using binaural alternate irrigation for 30 seconds with cold (30°C) and warm (44°C) water (AQSTM2.0, Micromedical Technologies, Chatham, USA). Unilateral weakness (UW) was calculated using the Jongkees Formula (UW=((RW+RC)-(LW+LC))/(RW+LW+RC+LC)x100). Response difference of > 20% between the two ears was defined as canal paresis. The patients were divided into two groups of unilateral weakness positive and unilateral weakness negative according to the caloric test results.

cVEMP

The surface electromyographic activity of the SCM muscle was recorded using an EP 25 device (Interacoustics Co., Assens, Denmark). The active electrode was put on the upper half of the ipsilateral SCM muscle, and the reference electrode was put on the suprasternal notch. During the recording, the seated patients were instructed to rotate their heads to the opposite side to the stimulated ear to activate the SCM. Background electromyographic activity was monitored visually for consistent tonic contraction. Short tone bursts (100 dB nHL and 500 Hz each, with a 1 ms risefall time and a 5 ms plateau time) were delivered monaurally via TDH 49P insert earphones. The stimulation rate was 5 Hz, and the analysis time was 60 ms. In total, 128 responses to stimuli were averaged, and the measurements were repeated twice to check test wave reproducibility. The latencies of the first positive peak (p13), the next negative peak (n23), and amplitude difference between the p13 and n23 amplitudes were measured. The interaural asymmetry ratio (IAR) was used for evaluating both ears' vestibular function. IAR is calculated using the Jongkees formula ((right-left)/(right+left)).

Spontaneous Nystagmus and Post-head Shaking Nystagmus

Spontaneous nystagmus: The patients were asked to look forward and eye movements were recorded for 30 seconds with visual fixation and 30 seconds without visual fixation using the goggles and the computer program (VisualEyes 4 channel, Micromedical Technologies, Chatham, USA). Nystagmus lasting more than 5 seconds was defined as pathological nystagmus.

Post-head shaking nystagmus: In the sitting position, the head was titled 30 degrees forward. The head was then shaken to the right and left for 20 seconds and eye movements were recorded after head shaking. Nystagmus lasting more than 5 seconds was defined as pathological nystagmus.

Statistical analysis of the data was made using IBM SPSS Statistics for Windows, version 22.0 software (IBM Corp., Armonk, New York, USA). The Chi-square test was used to compare the vHIT results with other test results such as the caloric test, spontaneous nystagmus, post-head shaking nystagmus, and cVEMP. P-value <0.05 was considered statistically significant.

RESULTS

Analysis of the results of 88 patients, comprising 39 (44.3%) males and 49 (55.7%) females with a mean age of 50.07±15.5 years was made. The distribution of the diseases of the 88 patients are shown in Table 1.

Abnormal vHIT (horizontal and/or vertical canals) was determined in 81.8% of the patients; canal paresis in 54.5%, abnormal cervical VEMP in 60.2%, spontaneous nystagmus in 23.9%, and post-head shaking nystagmus in 72.7%.

TABLE 1: Distribution of diseases.

Diagnosis	No. of patients	%
BPPV*	8	9.1
VN	25	28.4
MD	31	35.2
VM	11	12.5
VS	2	2.3
CV	11	12.5
Total	88	100

BPPV: Benign paroxysmal positional vertigo, VN: Vestibular neuritis, MD: Meniere's disease, VM: Vestibular migraine, VS: Vestibular schwannoma, CV: chronic vestibulopathy.* with comorbid vestibular condition (3 Meniere's disease, 2 vestibular migrain, 3 vestibular hypofunction in caloric irrigation).

Abnormal vHIT in the affected canal (4 horizontal canals, 4 posterior canals) was seen in all the 8 BPPV patients (8/8). In 4 of the BPPV patients (4/8) canal paresis was present, 4 (4/8) had abnormal cVEMP, 2 (2/8) had spontaneous nystagmus, and 7 (7/8) had post-head shaking nystagmus. Meniere's disease was determined in 3 patients; history of vestibular migraine (asymptomatic period) in 2 and vestibular hypofunction (in caloric irrigation) in 3.

Abnormal posterior canal vHIT and spontaneous nystagmus were seen in both patients (2/2) with vestibular schwannoma. However, normal caloric response was observed in both patients. Abnormal cVEMP and post-head shaking nystagmus were determined in 1 of these patients. Abnormal vHIT (horizontal and/or vertical canals) was observed in 29 of 31 patients with MD. In the VM, abnormal vHIT was observed 4 of 11 patients Vestibular test findings related to other diseases are shown in Table 2.

Abnormal lateral vHIT was seen in 74.5% of the patients with canal paresis and in 46.3% of the patients without canal paresis in caloric irrigation (Chi-square test, $p<0.05$) (Figure 1). Abnormal posterior vHIT was determined in 44.7% of the patients with canal paresis and in 65.9% of the patients without canal paresis in caloric irrigation (Chi-square test, $p<0.05$) (Figure 2). Abnormal anterior vHIT was determined in 8.5% of the patients with canal paresis and in 2.4% of the patients without canal paresis in caloric irrigation (Chi-square test, $p>0.05$).

DISCUSSION

Both lateral vHIT and the bithermal caloric test assess integrity of the VOR, which originates from the lateral semicircular canal. However, vHIT evaluates high frequency (4-5 Hz), while the caloric test evaluates low frequency (0.004 Hz) VOR response.[14] Many authors have concluded that vHIT is not an alternative to caloric test, but that the tests are complementary.[1-3] To save time in vestibular neuritis, Rambold et al. advocated using the vHIT first and only applying the caloric test in cases of unremarkable vHIT.[6] However, in Menière's disease and vestibular migraine, it was stated that applying caloric irrigation first might be more effective. It was reported by Rohrmeier et al. that the triple test including vHIT, spontaneous nystagmus and post-head shaking nystagmus could generally predict the canal paresis determined in the caloric test.[15] In the current study, abnormal lateral vHIT was determined in 74.5% of the patients with canal paresis and in 46.3% of the

TABLE 2: Percentages of abnormal vestibular tests in benign paroxysmal positional vertigo, vestibular neuritis, Meniere's disease, vestibular migraine, vestibular schwannoma and chronic vestibulopathy.

	vHIT	Caloric test	cVEMP	SN	PHS
MD	93.5% (29/31)	77.4% (24/31)	64.5% (20/31)	19.3% (6/31)	71% (22/31)
BPPV	100% (8/8)*	50% (4/8)	50% (4/8)	25% (2/8)	87.5% (7/8)
VN	72% (18/25)	40% (10/25)	64% (16/25)	16% (4/25)	84% (21/25)
VM	36.4% (4/11)	54.5% (6/11)	72.7% (8/11)	45.4% (5/11)	45.4% (5/11)
VS	100% (2/2)	0% (0/2)	50% (1/2)	100% (2/2)	50% (1/2)
CV	100% (11/11)	36.4% (4/11)	36.4% (4/11)	18.2% (2/11)	72.7% (8/11)
Total	81.8% (72/88)	54.5% (48/88)	60.2% (53/88)	23.9% (21/88)	72.7% (64/88)

vHIT: video head impulse test, CVEMP: cervical vestibular evoked myogenic potential, SN: spontaneous nystagmus, HSN: head shaking nystagmus, BPPV: Benign paroxysmal positional vertigo, VN: Vestibular neuritis, MD: Meniere's disease, VM: Vestibular migraine, VS: Vestibular schwannoma, CV: chronic vestibulopathy

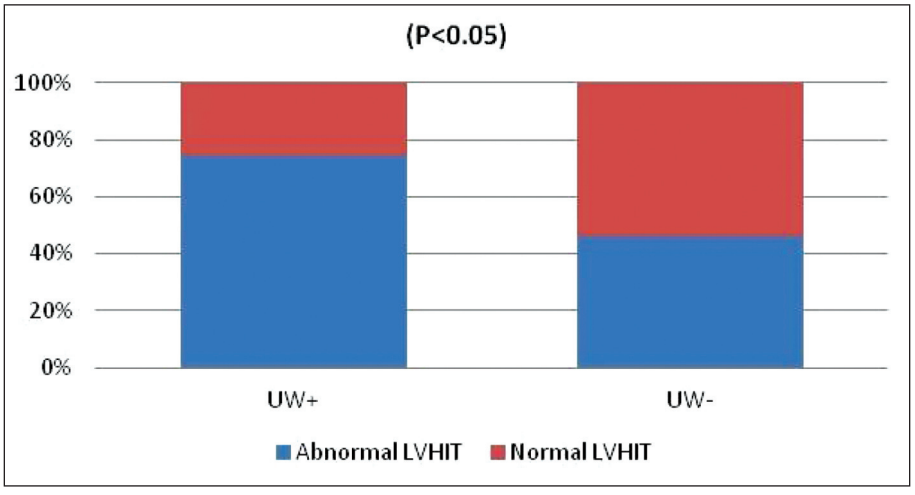

FIGURE 1: Comparison of the results of lateral vHIT and the caloric test. LVHIT: lateral video head impulse test, UW: unilateral weakness.

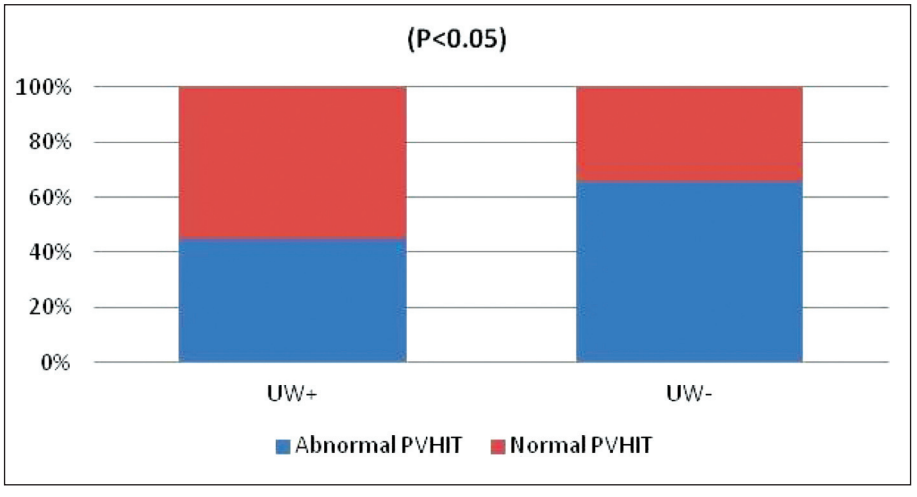

FIGURE 2: Comparison of the results of posterior vHIT and the caloric test. PVHIT: posterior video head impulse test, UW: unilateral weakness.

patients without canal paresis ($p<0.05$). Abnormal posterior vHIT was determined in 44.7% of the patients with canal paresis and in 65.9% of the patients without canal paresis ($p<0.05$). Abnormal lateral vHIT was seen to be more common in patients with canal paresis. In contrast, abnormal posterior vHIT was seen more often in patients without canal paresis. This difference between posterior and lateral vHIT can be explained by the localization of the lesion. Canal paresis and abnormal lateral vHIT are expected when the lesion affects the superior vestibular nerve, because this nerve innervates the cristae of the superior and lateral canals, the anterosuperior part of the macula of the saccule, and the macula of the utricle. However, canal paresis and abnormal horizontal vHIT are not expected in an inferior vestibular nerve lesion because the inferior vestibular nerve innervates the crista of the posterior canal and the main portion of the macula of the saccule.[16] Therefore, abnormal posterior vHIT is expected in a lesion affecting the inferior vestibular nerve. Consequently, these findings are consistent with the literature.

There were 2 patients in the study with vestibular schwannoma. The caloric responses of both these patients were within normal limits, and both patients had saccade in the posterior canal vHIT and more evident spontaneous nystagmus in the vertical component. Borgman reported that the majority of caloric

responses were normal in neurinoma originating from the inferior vestibular nerve.[17] Okada et al. examined 54 patients with small vestibular schwannoma and reported a normal caloric response in 44.4% and spontaneous nystagmus in 36.5%.[18] The findings found in our patients could be due to the lesions orginating from the inferior vestibular nerve.

Many studies have stated that the caloric test is more sensitive than vHIT in the assessment of horizontal VOR in Meniere's disease.[19-21] Blödow et al. researched Meniere's disease and vestibular migraine, which has similar symptoms, and found more abnormal results in Meniere's disease than in vestibular migraine in both the caloric test and vHIT.[3] Abnormal vHIT was found in the majority of patients with Meniere's disease (29/31) in the current study. This rate was lower in the vestibular migraine group (4/11).

The role of vHIT in the diagnosis of BPPV is not clear. In a study, it was shown that VOR gain was reduced in the affected canal in patients with posterior canal BPPV, but not affected in patients with horizontal canal BPPV.[22] Castellucci et al. have proposed to include vHIT in the test battery of patient with positional downbeat nystagmus due to benign paroxysmal positional vertigo involving the anterior canal or the non-ampullary arm of the posterior canal (apogeotropic variant), as it may provide clues to the differential diagnosis with central pathologies enabling the identification of the canal involved by BPPV.[23] In the current study, only 8 patients with BPPV who were applied all the vestibular tests were analyzed. vHIT was the first test in the audio-vestibular test battery of this study. Comorbid vestibular condition was suspected according to the vHIT results in all these patients and the whole test battery included the caloric test was then applied. Catch up saccades were observed on the affected canal in all the patients with BPPV (8 patients) in the current study. Of the 8 patients with BPPV, 4 had canal paresis, 4 had abnormal cVEMP, 2 had spontaneous nystagmus, and 7 had post-head shaking nystagmus. Three patients had Meniere's disease (asymptomatic period), 2 patient had a history of vestibular migraine (asymptomatic period), and 3 patients had only vestibular hypofunction (in caloric irrigation). In many studies, it has been reported that BPPV is associated with other vestibular diseases such as Meniere's disease, vestibular neuritis, vestibular migraine, and sensorineural hearing loss shows a high recurrence rate and requires more applications of the canalith repositioning maneuver.[24-26] Therefore, it is important to know about comorbid vestibular disorders in patients with BPPV. Information about the comorbid disease in the 8 patients with BPPV was provided by vHIT in the current study.

CONCLUSION

In the current study, the results showed that unilateral vestibular hypofunction could be determined largely by vHIT (81.8% (72/88)). The localization of pathology may be estimated by performing both lateral and vertical vHIT. It can be concluded that performing vHIT before Dix-Hallpike might be useful in predicting a comorbid disease and treatment success in patients with BPPV. In all these cases, vHIT alone does not have a diagnostic value, and these findings must be supported by other tests.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Levent Naci Özlüoğlu;* ***Design:*** *Sabuhi Jafarov, Evren Hızal;* ***Control/Supervision:*** *Evren Hızal, Levent Naci Özlüoğlu;* ***Data Collection and/or Processing:*** *Sabuhi Jafarov,Hüseyin Samet Koca;* ***Analysis and/or Interpretation:*** *Sabuhi Jafarov, Evren Hızal;* ***Literature Review:*** *Sabuhi Jafarov;* ***Writing the Article:*** *Sabuhi Jafarov;* ***Critical Review:*** *Evren Hızal.*

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