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Original Article

Caloric Analysis of Patients with Benign Paroxysmal Positional Vertigo

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OBJECTIVE: The aim of this study is to compare nystagmus characteristics after caloric irrigation in patients with lateral canal (LC) and posterior canal (PC) benign paroxysmal positional vertigo (BPPV) and to analyze the role of symptom duration.

MATERIALS and METHODS: A prospective study was conducted in 65 patients with BPPV (20 LC and 45 PC) who were subjected to caloric testing. Average slow-phase velocity and nystagmus duration were analyzed.

RESULTS: Caloric hypo-excitability was 20.4%. It was more evident in patients with apogeotropic-type LC-BPPV. The comparison of average slow-phase velocity of the nystagmus and nystagmus duration between selected types of BPPV for pathologic, non-pathologic, and the control ears after warm and cold stimulation was not statistically significant (p>0.05). No correlation was found between caloric results and symptom duration (p>0.05).

CONCLUSION: Some patients presented caloric hypo-excitability. Reliability of caloric testing to differentiate the ear with normal and abnormal vestibular function in different types of BPPV was low. No difference was found in the analysis of the impact of symptom duration. Caloric testing is not an ideal tool to study BPPV.

KEYWORDS: Benign paroxysmal positional vertigo, caloric testing, nystagmus

INTRODUCTION

Positional vertigo following sudden head motion in patients with benign paroxysmal positional vertigo (BPPV) is assumed to be due to freely floating otoconia inside the semicircular canals or those adhering to the cupula which make labyrinth sensitive to gravitational forces [1]. The majority of patients have quick relief of symptoms after repositioning maneuvers, although underlying pathology is obscure. Origin of these deposits is claimed to be due to degeneration of utricular neuroepithelium. Functional studies are needed to exclusively detect possible organic pathology of the utricule. Innervation of utricule is provided by superior vestibular nerve which also collects impulses from lateral and superior semicircular canals. The inferior vestibular nerve is connected to the posterior semicircular canal and the saccule.

Caloric testing was first studied by the Nobel Prize winner Robert Barany in 1906, and later it was introduced to the otologic practice by Fitzgerald and Hallpike [2] in 1942. Videonystagmograpy (VNG) with caloric stimulation has been widely used in the analysis of severity of vestibular disorders. It reflects the degree to which the vestibular system is responsive and how symmetric the responses are between left and right. Caloric irrigation through the ear canal selectively stimulates the lateral canal [3]. However, studies indicate the contribution of other semicircular canals to the final response. Gacek et al. [4] have found severe dysfunction after caloric stimulation in seven patients who had singular neurectomy. Sensitivity of caloric stimulation to detect the vestibular pathology is subject to discussion [5]. Some problems may remain undiagnosed unless they cause severe vestibular dysfunction. The aim of this study is to analyze the incidence of caloric hypo-excitability, to investigate the role of symptom duration, and to compare the caloric responses in patients with lateral canal (LC-BPPV) and posterior canal (PC-BPPV).

MATERIALS and METHODS

Sixty-five patients with BPPV who had been recruited between 2011 and 2014 were subjected to bithermal caloric testing with VNG (Micromedical Technologies, Inc., USA). A verbal ainformed consent was obtained from each patient and the control subjects. The procedures were in accordance with the ethical standards of the Declaration of Helsinki and of the institutional

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review board. The study was approved by Hospital's Ethics Committee. Main inclusion criteria were normal otoscopic examination and normal pure tone hearing thresholds. Those with hearing loss, tinnitus, spontaneous nystagmus, abnormal ear drum, other vestibular or neurologic problems, history of hypertension, eye and ear surgery and those who used medication before testing were excluded. Data were collected in a referral community hospital. Fifteen age-matched subjects who had no balance and hearing problems served as the control group.

Goggles with closed infrared wireless camera system (open eyes, closed vision) were used (Micromedical Technologies, Inc., USA). All patients were initially tested for spontaneous nystagus in the seated primary gaze position. They were later tested for LC-BPPV and PC-BPPV. The type, duration, and direction of nystagmus were recorded. Presence of latency, short duration, and adaptation of transient nystagmus were noted to confirm peripheral-type positional nystagmus. Finally, bithermal caloric testing was performed with the subject in supine position having his/her head 30 degrees elevated from the horizontal plane. Each ear was irrigated with 250-mL 30° cold and 44° hot water for 30 s. The patient was distracted with questions during recording which was maintained for 5 min for the last visible nystagmus. The procedure was carried out in a similar fashion for the next irrigation after 5 min always in the same order (left warm, right warm, left cold, and right cold). Unilateral hypo-excitability was defined according to the Jongkee's formula as the difference between the sum of the nystagmus of caloric stimulation of right and left ear is greater than 20%. Directional preponderance was defined as the difference between the sum of right and left beating nystagmus is greater than 30% [6]. Average slow-phase velocity was defined as degrees per second within a 10-s time frame where the frequency of nystagmus was maximum. Nystagmus duration was defined as seconds from the beginning of the caloric irrigation to the last visible nystagmus. Average slow-phase velocity and nystagmus duration were compared between the patients with LC-BPPV and PC-BPPV for each caloric stimulation. Patients were analyzed according to the duration of symptoms as those with symptoms less or more than 2 months.

Statistical Analysis

The one-way ANOVA and chi-square "goodness-of-fit" tests were used for comparative analysis. Statistical significance was set at $p<0.05$.

RESULTS

Demographic data are shown in Table 1. There were 28 men and 37 women in the study group with age ranging from 27 to 77 y (mean age: 43.73±11.70 y; men: 44.79±12.37 y; women: 42.88±11.23 y, p=0.519). There were seven men and eight women in the control group with age ranging from 26 to 48 y (mean age: 45.32±5.50 y). The duration of symptoms was ranging between 2 days and 9 months. There were 45 patients with PC-BPPV (19 right ear and 26 left ear) and 20 patients with LC-BPPV. Twelve patients were geotropic-type LC-BPPV (6 right ear and 6 left ear) and eight patients were apogeotropic-type LC-BPPV (4 right ear and 4left ear). Thirty-nine patients (60%) had symptoms less than 2 months and 26 patients had symptoms more than 2 months. All patients had recordable caloric responses. Five patients with PC-BPPV had hypo-excitability on the pathologic side. One patient had directional preponderance (caloric stimulation of the pathologic side with cold and warm water provided stronger nystagmus than that of non-pathologic side). Caloric abnormality for patients with PC-BPPC was 13.3% (6 of 45). Three patients with apogeotropic-type and two patients with geotropic-type LC-BPPV had caloric hypo-excitability (3 of 8, 37.5% and 2 of 12, 16.6%). The overall abnormality was 20.4% (11 of 45). Comparison of the average-slow phase velocity of the nystagmus and average nystagmus duration for patients with LC- and PC-BPPV and non-pathologic ears after warm and cold stimulation was not statistically significant (Tables 2 and 3, p>0.05), and the comparison of the average slow-phase velocity of the nystagmus and average nystagmus duration for BPPV patients with symptoms less than and more than 2 months after warm and cold stimulation revealed no statistically significant differences between the groups (Tables 4, 5, p>0.05).

Table 1. Demographic data of the patients and the control subjects

	Study group (65)	Control group (15)
Gender	28 M, 37 F (0.756)	7 M, 8 F (0.875)
Mean age	43.73±11.70	45.32±5.50

M: male; F: female

Table 2. Average slow phase velocity (deg/sec) in patients with BPPV. No statistical difference was found in comparison of pathologic and healthy side

	Pathologic side		Non-pathologic side		
Groups	Warm	Cold	Warm	Cold	p
PC-BPPV	21.25±13.51	22.68±11.1	22.33±14.3	25.42±11.81	W; 0.573 C; 0.320
LC-Geotropic	32.54±22.73	25.45±11.57	34.45±22.75	28.9±13.05	W; 0.843 C; 0.519
LC-Apogeotropic	17.00±13.48	21.25±16.86	17.5±13.71	22.37±17.78	W; 0.921 C; 0.810
Control	LE; 16±8.18 RE;16.2±5.54	LE; 16.4±2.88 RE; 22.8±4.76	LE; 16±8.18 RE;16.2±5.54	LE; 16.4±2.88 RE; 22.8±4.76	
p	0.094	0.678	0.061	0.413	

LE: left ear; RE: right ear; W: comparison of pathologic and healthy ears after warm stimulation; C: comparison of pathologic and healthy ears after cold stimulation; PC-BPPV: posterior canal-benign paroxysmal positional vertigo; LC: lateral canal

Table 3. Duration of induced nystagmus (sec) in patients with BPPV. No statistical difference was found in comparison of pathologic and healthy side

	Pathologic side		Non-pathologic side		
Groups	Warm	Cold	Warm	Cold	p
PC-BPPV	186.17±17.01	191.22±12.56	188±17.36	191.06±8.28	W; 0.370 C; 1000
LC-Geotropic	182.18±17.38	187.18±15.7	187.9±14.91	194.27±7.45	W; 0.415 C; 0.191
LC-Apogeotropic	182±26.88	183.37±29.06	183±29.42	191.5±9.78	W; 0.921 C; 0.466
Control	LE; 195.8±4.96 RE; 188.4±12.5	LE; 190.6±2.6 RE; 194.6±2.07	LE; 195.8±4.96 RE; 188.4±12.5	LE; 190.6±2.6 RE; 194.6±2.07	
p	0.635	0.601	0.829	0.692	

LE: left ear; RE: right ear; W: comparison of pathologic and healthy ears after warm stimulation; C: comparison of pathologic and healthy ears after cold stimulation; PC-BPPV: posterior canal-benign paroxysmal positional vertigo; LC: lateral canal

Table 4. Comparison of average slow phase velocity (deg/sec) in patients with short and long term symptoms. No statistical difference was found

	Pathologic side		Non-pathologic side		
Groups	Warm	Cold	Warm	Cold	p
Patients with symptoms less than 2 months No; 36	23.85±18.35	23.6±11.38	25.82±19.01	26.22±11.3	W; 0.633 C; 0.275
Patients with longer symptoms No; 29	20.48±12.32	22.41±12.66	21.17±12.82	24.58±14.76	W; 0.778 C; 0.505
p	0.402	0.690	0.265	0.618	

W: comparison of pathologic and healthy ears after warm stimulation; C: comparison of pathologic and healthy ears after cold stimulation

Table 5. Comparison of duration of induced nystagmus (sec) in patients with short and long term symptoms. No statistical difference was found

	Pathologic side		Non-pathologic side		
Groups	Warm	Cold	Warm	Cold	p
Patients with symptoms less than 2 months No; 36	186.54±15.5	192.82±7.71	188.74±13.05	191.88±7.95	W; 0.524 C; 0.256
Patients with longer symptoms No; 29	183.06±21.27	185.58±21.51	187.37±21.58	191.41±8.82	W;0.445 C; 0.182
p	0.453	0.068	0.752	0.823	

W: comparison of pathologic and healthy ears after warm stimulation; C: comparison of pathologic and healthy ears after cold stimulationparoxysmal positional vertigo

DISCUSSION

Bithermal caloric testing is one of the most commonly used and earlier vestibular testing methods. Caloric data are now analyzed with a computerized system based on peak slow-phase velocity of the evoked nystagmus. It has been subject of many discussions that caloric stimulation of the vestibular system is more conveniently performed but is less accurate thanseveral other methods available to investigators. However, despite variables such as different caloric methodologies, caloric order effects, and technical challenges faced by individuals performing it, the test remains the standard in many vestibular laboratories. In search of vestibular dysfunction and its relation with the treatment outcome and the recurrence, caloric testing of the vestibular system in patients with BPPV presents conflicting results. On the other hand, the comparative analysis of caloric test results in patients with LC-BPPV (ageotropic- and geotropic-type) and PC-BPPV and the effect of symptom duration on caloric responses was not reported before.

Irrigation of the ear canal with hot and cold water creates an endolymphatic flow in opposite directions. Warm water causes an ipsilateral firing of the vestibular afferent nerve in which the situation more or less mimics a head turn to the ipsilateral side resulting with quick eye movements to the ipsilateral eye. Cold water decreases the rate of ipsilateral vestibular afferent firing. Then, the eyes turn toward the ipsilateral ear resulting with nystagmus beating to the contralateral ear. Water irrigation of the external canal mainly stimulates the lateral canal, as it is located in the axis of the ear canal. However, the contribution of other semicircular canal to the overall response is likely.

Korres et al. [5] have analyzed the caloric responses in 168 patients with BPPV and have found canal paresis in 22% and directional preponderance in 13.7% of patients. Strupp et al. [7] have pointed out the reversibility of caloric hypo-excitability in case of LC-BPPV after liberatory maneuver. On the other hand, Molina et al. [8] have used caloric testing as a monitoring tool. They have found that 25% of patients with BPPV (16 of 54) had canal paresis at the diagnosis and 16% (9 of 56) still had canal paresis 1 y later. They have reported that canal paresis was not associated with a lower outcome to repositioning maneuver. It was interesting to observe the normalization of caloric responses over time with the resolution of positional symptoms [8]. However, the impact of symptom duration was not clear. The incidence of canal paresis in this series is 20.4%, and it is similar to the reports from other studies.

We have found no correlation between the caloric results and the symptom duration. However, the higher incidence of caloric abnormality in patients with apogeotropic-type LC-BPPV is a new finding. Does this result indicate an associated cupular pathology? Detailed analysis with larger series is needed before answering the question. However, otoconia attached to the cupular surface or located inside the canal in the vicinity of the cupula could somehow be related to the lower firing rate after bithermal caloric stimulation. Caloric testing is not an ideal tool to study BPPV. Caloric testing is considered as equivalent to only a low-frequency audiometric testing of the hearing [9]. Iwasaki et al. [10] have reported abnormal vestibular-evoked myogenic potentials (VEMP) in some patients with BPPV having normal caloric responses. VEMP abnormality seems to be more correlated with the recurrence of symptoms in patients with BPPV [11].

In conclusion, it is believed that degeneration of the utricular neuroepithelium is the source of freely floating otoconia inside the semicircular canals or those adhering to the cupula which induce the positional vertigo in patients with BPPV and raises a question of possible organic pathology. Caloric irrigation through the ear canal mainly stimulates the lateral canal and the superior vestibular nerve that innervates the utricule. Therefore, caloric testing mainly stimulates superior vestibular nerve even though minor contribution of inferior vestibular nerve is possible. While many studies have focused on the caloric excitability of patients with BPPV, no studies have compared symptom duration and the caloric results of lateral and posterior canal vertigo. We have found that ability of caloric testing to differentiate the ear with normal and abnormal vestibular function in patients with BPPV to be low. In the present study, no caloric difference was found in patients with LC-BPPV and PC-BPPV.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Anadolu Medical Center.

Informed Consent: Verbal informed consent was obtained from patients who participated in this study.

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