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Evaluation of Vertical Semicircular Canal Function by the Caloric Test

— A Study on Patients with Benign Paroxysmal Positional Vertigo —

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The morbidity of benign paroxysmal potisional vertigo (BPPV) was investigated from the functional standpoint by analyzing nystagmus elicited by the caloric test.
As a result of an investigation of the three (horizontal, vertical and torsional) components of the nystagmus elicited by the caloric stimulus (cold water), the vertical nystagmus differed in direction between the left and the right ear in 3 out of the 4 BPPV cases. The vertical nystagmus elicited by the caloric stimulus reflected the functions of the anterior and posterior semicircular canals, and investigation of the difference in function between the anterior and posterior semicircular canal from the direction of the vertical nystagmus appeared to be feasible.

Key Words: Vertical semicircular canal, Benign paroxysmal positional vertigo, Caloric test

INTRODUCTION

As a result of a histopathological study of benign paroxysmal positional vertigo (BPPV), Schuknecht [4] reported on cupulolithiasis, in which a degenerated otolith is present at the cupulla of the posterior semicircular canal. McClure [3] reported participation of the horizontal semicircular canal in the morbidity. Brandt [1] discussed the concept of canalolithiasis in BPPV in view of the otolith in the horizontal semicircular canal. We used an infrared CCD camera to record nystagmus and a computer system to analyze nystagmus, and this method made it possible to examine the functions of the horizontal, anterior and posterior semicircular canals [2]. In this study, the caloric test was conducted on the vertical semicircular canal in 4 BPPV patients to investigate morbidity.

SUBJECTS AND METHODS

The subjects of the study consisted of one male and 3 females with posterior semicircular canal variants of BPPV. The mean age was 51.3 years (32 to 65 range). BPPV is characterized by 1) latency: vertigo and nystagmus start one or more seconds after the head is tilted; 2) duration: less than 1 minute; 3) linear-rotary nystagmus; 4) reversal; and 5) fatigability [1]. All subjects in this study met all of the above criteria. None of the patients had a history of apparent head trauma. An infrared CCD camera and a personal computer system to analyze movements of the eyeballs were used to analyze the nystagmus. For the caloric nystagmus test, a small quantity (5cc) of cold water (20℃) was used as the stimulus. The test was performed with the head tilted at 30° forward from the supine position. The nystagmus thus evoked was recorded with an infrared CCD camera and the direction of the nystagmus was analyzed utilizing a personal computer system for ocular movements. At this time, the CCD camera was attached over the left eye. To date, there have been certain inconsistencies in indicating the direction of nystagmus, i.e., in the case of horizontal or vertical components, it was

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indicated according to the subject's position, while the torsional element was indicated from the position of the investigator. In the present study, all directional indications relating to horizontal, vertical, and/or torsional components, such as left or right, upward or downward, and clockwise or counterclockwise, were expressed in accordance with the subject's position. The directions of the rapid phase were also used to represent the directions of nystagmus. We determined that the affected side was in the lowered position, when vertigo and/or nystagmus occurred in the head-hanging position, rotated to the left or right.

RESULTS

The directions of the three components of nystagmus, i.e., horizontal, vertical and torsional evoked during the caloric test with cold water were investigated. In one of the 4 cases, the directions of the 3 components of nystagmus were found to be symmetric between the left and right ears (Case No. 4). The directions of the horizontal and torsional nystagmus were found to be symmetric between the left and right ears in all 4 cases. Regarding vertical nystagmus, there were differences between the left and right ears, with upward vertical nystagmus found on the affected sides in all cases (Case No. 1, 2, and 3) (Table 1).

DISCUSSION

Nystagmus evoked by the caloric test was investigated with respect to its three components, i.e., horizontal, vertical and torsional nystagmus. The horizontal semicircular canal is considered to be almost in the vertical position when the subject takes the supine position with head tilted at 30° forward. It is generally considered in this head position, the cold water stimulus initiates ampullofugal endolymphatic convection flow inside the horizontal semicircular canal, and as a result, the activity of the horizontal semicircular canal is inhibited.

Although it is not known what occurs in the vertical semicircular canal, in the anterior semicircular canal, ampullopetal endolymphatic convection flow probably starts and the activities are inhibited. Also, sufficient knowledge has not been obtained concerning what kind of the convection flow occurs in the posterior semicircular canal. However, the research of Suzuki and Bender [4] (Table 2), in which the excitability of a single semicircular canal by electric stimulus was investigated in cats, suggested that the upward vertical nystagmus and the counterclockwise torsional nystagmus are evoked when activities of the right anterior semicircular canal are inhibited, and the downward vertical nystagmus and counterclockwise torsional nystagmus occur when activities of the right posterior semicircular canal are inhibited. We believe that in the case of inhibited activities of the left anterior semicircular canal, upward vertical nystagmus and clockwise torsional nystagmus are evoked, and if the activity of the left posterior semicircular canal is inhibited, downward vertical and clockwise torsional nystagmus are evoked. If the inhibition elicited by the cold water stimulus in the anterior semicircular canal of the right ear equals that of the posterior semicircular canal, then vertical nystagmus would be offset and only counterclockwise torsional nystagmus would be evoked. If the activity of the anterior semicircular canal exceeds that of the posterior semicircular canal, upward vertical nystagmus and counterclockwise torsional nystagmus would be evoked, and if the activity of the posterior

Table 1 Directions of three components of nystagmus induced by the caloric test

Subject No. (affected side)	Nystagmus					
	Horizontal		Vertical		Tosional	
	R	L	R	L	R	L
1 55y/o F (R)	L	R	UW	N	CCW	CW
2 65y/o M (R)	L	R	UW	N	CCW	CW
3 53y/o F (L)	L	R	N	UW	CCW	CW
4 32y/o F (L)	L	R	UW	UW	CCW	CW

R=right; L=left UW=upward; N=none CCW=counterclockwise; CW=clockwise

Table 2 Directions of nystagmus evoked by stimulus to the semicircular canals

Activity \ Canals		HC	AC	PC	AC=PC	AC>PC	AC<PC
Excitation	Right	R	DW/CW	UW/CW	CW	DW/CW	UW/CW
	Left	L	DW/CCW	UW/CCW	CCW	DW/CCW	UW/CCW
Inhibition	Right	L	UW/CCW	DW/CCW	CCW	UW/CCW	DW/CCW
	Left	R	UW/CW	DW/CW	CW	UW/CW	DW/CW

R=right; L=left UW=upward; DW=downward; N=none CCW=counterclockwise; CW=clockwise
HC=horizontal semicircular canal; AC=anterior semicircular canal; PC=posterior semicircular canal
This table is orginated from references 5) and 6).

semicircular canal exceeds that of the anterior semicircular canal, downward vertical and counterclockwise torsional nystagmus would be evoked. If the inhibition caused by the cold water stimulus in the anterior semicircular canal of the left ear is equal to that of the posterior semicircular canal, then vertical nystagmus would be offset and clockwise torsional nystagmus would be evoked. If inhibition of activities of the anterior semicircular canal exceeds that of the posterior semicircular canal, upward vertical and clockwise torsional nystagmus would be evoked, and if the activity of the posterior semicircular canal exceeds that of the anterior semicircular canal, downward vertical as well as the clockwise torsional nystagmus would be evoked. Further, if the activity of the anterior semicircular canal is inhibited, and that of the posterior semicircular canal is excited, and the activity of the anterior semicircular canal is equal to that of the posterior semicircular canal in the right ear, torsional nystagmus would be offset and only upward vertical nystagmus would be evoked. When the activity of the anterior semicircular canal exceeds that of the posterior semicircular canal, upward vertical nystagmus and counterclockwise torsional nystagmus would be evoked, and if the activity of the posterior semicircular canal exceeds that of the anterior semicircular canal, upward vertical nystagmus as well as the clockwise torsional nystagmus would be evoked. In the left ear, if activities of the anterior and the posterior semicircular canals are the same, the torsional nystagmus would be offset and only upward vertical nystagmus would be evoked. If the activity of the anterior semicircular canal exceeds that of the posterior semicircular canal, upward vertical nystagmus and clockwise torsional nystagmus would be evoked, and when the activity of the posterior semicircular canal exceeds that of the anterior semicircular canal, upward vertical nystagmus and counterclockwise torsional nystagmus would be evoked (Table1).

When the present results were reviewed in view of the above theory, it was evident that activities of both the anterior and the posterior semicircular canals should be considered as inhibited. In other words, our interpretation is as follows: in Cases No. 1 and 2, while upward vertical nystagmus and counterclockwise torsional nystagmus were recognized on the affected side because the activity of the anterior semicircular canal was in excess of that of the posterior semicircular canal in the right ear; in the left ear, only clockwise torsional nystagmus was recognized, but no vertical nystagmus was evoked because the activities of the anterior and the posterior semicircular canal were equal. In Case No. 3, counterclockwise torsional nystagmus was recognized but no vertical nystagmus was evoked in the right ear since the activity of the anterior semicircular canal was equal to that of the posterior semicircular canal; but in the left ear on the affected side, the activity of the anterior semicircular canal was in excess of that of the posterior semicircular canal, and upward vertical and clockwise torsional nystagmus were recognized. In Case No. 4, the activiy of the anterior semicircular canal exceeded that of the posterior semicircular canal in both left and right ears; therefore, upward vertical nystagmus and the counterclockwise torsional nystagmus were seen in the right ear, and upward vertical and clockwise rotatory nys-

tagmus in the left ear. Yagi, et al. [6] reported that as a result of the caloric test with cold water stimulus applied to the right ear of subjects in the supine and prone positions, leftward, horizontal nystagmus and the counterclockwise torsional nystagmus in the supine position, and the rightward, horizontal nystagmus and clockwise torsional nystagmus in the prone position were identified in all subjects. The direction of the vertical nystagmus was different in each case in both positions. The above results in the supine position agreed with those of our study. They considered that it was likely that activities of all three, i.e., the horizontal, anterior and posterior semicircular canals were inhibited in the supine position and in the prone position which involved 180° change from the previous position, the activity of the horizontal semicircular canal was excited, and the activiy of the anterior and posterior semicircular canals were inhibited; however, in reality the activities of all three semicircular canals seemed to be excited, suggesting the difficulty in elucidating these relations based only on the convection flow theory.

The results of our cold water stimulus test showed that activities of all three semicircular canals appeared to be inhibited because the activity of the horizontal semicircular canal seemed inhibited since the leftward horizontal nystagmus in the right ear, and the rightward nystagmus in the left ear were present in all patients. Activities of the anterior and posterior semicircular canals were inhibited in both ears in view of the directions of the vertical and torsional nystagmus evoked from the vertical semicircular canal. In this regard, it may be difficult to elucidate the mechanism of caloric nystagmus based only on the endolymphatic convection flow theory.

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