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Original Article

Changes in the Results of the Subjective Visual Vertical Test After Endolymphatic Sac Drainage for Intractable Meniere's Disease

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OBJECTIVE: To investigate otolithic function before and after endolymphatic sac drainage (ELSD) for Meniere's disease (MD) by using the subjective visual vertical test (SVV) in the upright and tilted positions.

METHODS: Eighteen patients with definite unilateral MD diagnosed in accordance with the American Academy of Otolaryngology Head and Neck Surgery criteria in 1995 and Barany Society criteria in 2015 were included. SVV in the upright position and the head-tilt position was performed preoperatively and on postoperative days 1, 5, 8, 28, and 112. Changes in the results of SVV in the upright position (UP-SVV) and head-tilt perception gain (HTPG) after surgery were measured.

RESULTS: The average UP-SVV values significantly changed from 0.05° by the affected side before surgery to 2.5° by the unaffected side on the fifth postoperative day, followed by recovery to the normal range by the eighth postoperative day. The HTPG values for the unaffected side showed the maximum increase on postoperative day 5 during the present study period, although the values in the affected side did not alter significantly.

CONCLUSION: ELSD for MD is a surgical treatment that involves less risk of otolith function damage and abnormalities in gravitational cognition. SVV in the head-tilt position could be one of the neuro-otologic examinations used to easily understand the vestibular compensatory process.

KEYWORDS: Meniere's disease, endolymphatic sac drainage, otolithic function, subjective visual vertical test

INTRODUCTION

Meniere's disease (MD) is a disorder of the inner ear that causes vertigo lasting from minutes to hours, with fluctuating progressive sensorineural hearing loss and aural pressure. The symptoms can be reduced by a combination of medical therapy, psychological counseling and reassurance, and lifestyle and dietary changes.[1-6] When conservative medical treatments fail to control symptoms, surgeries are usually performed according to the treatment guidelines for MD.[7] Surgical procedures can be categorized as conservative or destructive. Of the surgical options, endolymphatic sac drainage (ELSD) provides the greatest hearing preservation.[8,9] Many authors consider ELSD as an effective surgical procedure, since it shows approximately 80% effectiveness in long-term vertigo control and between 71.6% and 86.5% effectiveness in maintaining hearing.[10-12] Most studies on surgical treatment of MD have focused on vertigo and hearing preservation. Given the possibility of bilateral disease in some MD patients, it may be important to maintain vestibular function on the first side to control vertigo. However, only a few studies have reported the effect of this surgery on vestibular function.[13,14]

The subjective visual vertical test (SVV) is a vestibular function evaluation tool that can assess otolithic function and the graviceptive pathway.[15,16] Earlier studies investigating SVV showed a 10° to 30° tilt toward the operated ear after unilateral peripheral surgical procedures for vestibular deafferentation, such as vestibular neurectomy and labyrinthectomy.[17] However, the time course of the SVV profile after ELSD remains unclear. SVV is usually performed in the upright position, but recent reports indicate that otolith functions and graviceptive pathway can be evaluated in detail by performing SVV in the head tilt position.[18] There are systematic errors in the perceived upright orientation with a lateral head tilt. Usually, at small head tilt angles, SVV errors are in

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the opposite direction of the head tilt, reflecting overcompensation for the amount of tilt. This finding, which reflects overestimation of upright orientation, is known as the E-effect. The E-effect presents less consistently, and variability of SVV errors has been attributed to a tilt-dependent noise in the otolith and proprioceptive inputs.[19] We hypothesized that measuring the magnitude of this E-effect separately for the left and right sides would allow us to assess the temporal variation in head tilt perception and more closely assess the effect of surgical manipulation on gravity perception.

In the present study, we aimed to investigate otolithic function before and after ELSD by using SVV in the upright and tilt positions.

METHODS

Patients

In the present study, 18 patients with a clinical diagnosis of unilateral MD (8 right ears and 10 left ears) according to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) guidelines in 1995[7] and Barany Society criteria in 2015[20] received ELSD with pre/postoperative SVVs. All patients had intractable MD, defined as recurrent vertigo/dizziness and fluctuating or progressive hearing loss for at least 6 months, persisting despite systematic medical treatment and psychological management (Table 1). They included 12 men and 6 women, with an age range of 18-74 years (mean, 57.2 years). The interval between the first vertigo attack or cochlear symptoms to operation (interval from onset to operation) ranged from 6 to 480 months (median, 44.0 months).

The Medical Ethics Committee of our university approved this study (certificate number: 916-5). In accordance with the Declaration of Helsinki, all subjects provided written informed consent after receiving a detailed explanation of the impending procedures.

Surgical Technique

Kitahara et al. reported an ELSD procedure that was performed with steroids.[12] Briefly, a simple mastoidectomy is performed to clearly expose the endolymphatic sac, opened with an L-shaped incision, and filled with 20 mg of prednisolone (Predonine; Shionogi, Japan). Next, a bundle of absorbable gelatin film (Gelfilm; Pfizer, Japan) is inserted into the sac, and an absorbable gelatin sponge soaked in high-density (3.3 mg/mL) dexamethasone (Decadron, Aspen Japan, Japan) is inserted. Small pieces are placed inside and outside the sac.[21]

Surgical Results

Vertigo control and hearing improvement were assessed at the 2-year follow-up in accordance with the 1995 AAO-HNS criteria.[7] The proportion of patients without vertigo was 88.8% (16/18), while that of patients with a hearing improvement of >10 dB was 22.2% (4/18). However, vertiginous and hearing symptoms were not so stable during the convalescent period immediately after surgery.

Examination Procedure

The SVV was performed using a simple examination system (HT-SVV system, UNIMEC, Japan). The patient sat 60 cm in front of the bar display box and wore goggles to eliminate any visual reference cues outside the bar. The SVV was performed in three head positions for each participant: upright, with a head tilt of approximately 30° toward the right, and with a head tilt of approximately 30° toward the left at the beginning of the test, subjects were asked to slowly tilt the head to the right or left according to the examiner's

Table 1. Summary of 18 Patients With Intractable Meniere's Disease

Case No	Age (Year)	Sex (M/F)	Interval From Onset to Operation (Months)	Operation Side (R/L)	Preoperative UP-SVV (°)
1	57	M	12	R	1.50
2	45	M	50	R	0.67
3	66	M	120	R	2.50
4	18	F	11	R	−1.67
5	66	M	480	R	0.00
6	72	M	6	R	−1.33
7	67	F	39	R	−2.67
8	66	M	48	R	−2.50
9	66	M	14	L	1.50
10	49	F	49	L	1.50
11	74	F	36	L	−1.50
12	55	M	12	L	1.33
13	48	M	60	L	2.16
14	43	M	40	L	1.50
15	61	M	40	L	−1.00
16	54	M	180	L	−0.33
17	62	F	140	L	−1.67
18	61	F	230	L	0.83

The cases involve 12 males and 6 females, with ages ranging from 18 to 74 years (mean, 57.2 years). The interval between the first vertigo attack or cochlear symptoms to operation (interval from onset to operation) ranged from 6 to 480 months (median, 44.0 months). One patient showed abnormal tilts of UP-SVV before the operation.
M, male; F, female; R, right; L, left; UP-SVV, upright subjective visual vertical test.

instructions, while keeping the eyes closed and the trunk upright. After the head remained stationary, participants were asked to open their eyes and use the keypad to answer the subjective vertical axis. At the same time, the head roll tilt angle was monitored using a linear accelerometer (CXL04GP3; Crossbow Japan, Japan) attached to a head cap. This trial was repeated 14 times (4 times in each tilt condition and 6 times in the upright condition) in pseudo-random order. We chose a 30° head tilt because if the angle was 30° in a healthy person, there was little variation in SVV in a preliminary experiment.[22]

The measurements were performed preoperatively and at postoperative days 1, 5, 8, 28 (1 M), and 112 (4 M).

Assessment

The upright SVV (UP-SVV) deviation was calculated in relation to the earth vertical with an accuracy of 0.1° units, and the average value of 6 measurements was used. All data were normalized to the affected side, and deviations to the affected side were considered positive values and deviations to the unaffected side were considered negative values.

The results of the head tilt SVV and the head tilt angle at that time were used to calculate the head tilt perception gain (HTPG) to indicate the direction and magnitude of the E-effect. All data for the head tilt SVV and head tilt angle were normalized with positive values for the affected side and negative values for the unaffected side. The following equation was used to calculate the head tilt perception, as shown in Figure 1:

$$\text{head tilt perception} = \text{head tilt angle} - \text{head tilt position SVV}$$

The slope in the regression equations for UP-SVV and head-tilt SVV when the *x*-axis represented the head tilt angle and the *y*-axis represented the head tilt perception was defined as the HTPG. An HTPG higher than 1 indicated that the E-effect occurred in the opposite direction of head tilt, while an HTPG lower than 1 indicated that the E-effect occurred in the same direction as the head tilt. When the HTPG equaled 1, the E-effect did not occur.

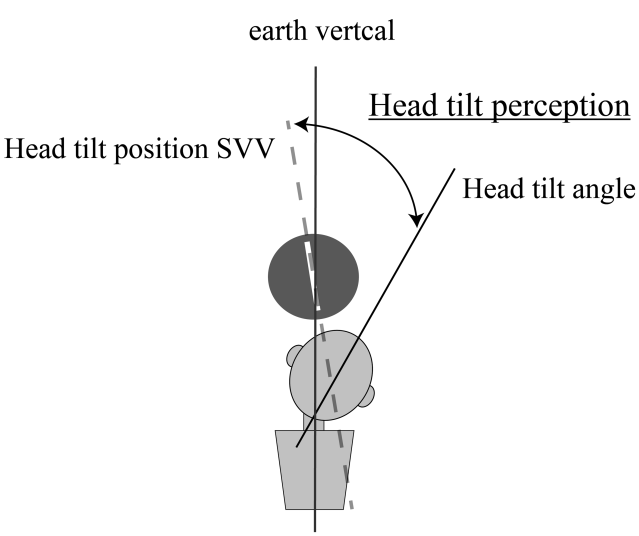

Figure 1. Schematic representation of SVV recordings. The solid line is the angle of the actual head tilt in the case. The dotted line is the head-tilt position SVV, which is the angle at which the case responded with a subjective vertical position. Positive values indicate deviations from the vertical to the clockwise, and negative values indicate deviations in the direction of the counterclockwise. The head-tilt perception is defined as the value obtained by subtracting the head-tilt position SVV from the head-tilt angle. SVV, subjective visual vertical test.

Data Analysis

The statistical package for social sciences, SPSS 25 (SPSS Inc., Chicago, USA), for Windows was used for statistical analysis. Normal distributions of all data were tested by the Shapiro–Wilk test. A one-way repeated measure analysis of variance (ANOVA) was used to compare the mean SVV and HTPG for time. The Tukey–Kramer method was used for post hoc analysis of the differences between each time point. The significance level was set at less than 5%.

RESULTS

All patients completed the study, and no adverse effects were reported. The one-way repeated measures ANOVA revealed significant differences in the mean UP-SVV values among time points (preoperative: 0.05° ± 1.66°; postoperative day 1: −1.78° ± 4.15°; postoperative day 5: −2.54° ± 2.31°; postoperative day 8: −1.59° ± 2.06°; postoperative day 28 [1 M]: −1.04° ± 1.78°; postoperative day 112 [4 M]: 0.52° ± 2.06°; $F = 3.977$, $P = .0025$; Figure 2). The post hoc tests of the mean value indicated that the value on postoperative day 5 was significantly smaller than that obtained preoperatively (95% CI: −4.97 to −0.20, $P = .026$) and on postoperative day 112 (CI: −5.44 to −0.68, $P = .0042$).

In addition, there was a significant difference in the mean values of HTPG for the non-operative side among time points (preoperative: 1.02 ± 0.19; postoperative day 1: 1.08 ± 0.13; postoperative day 5: 1.20 ± 0.25; postoperative day 8: 1.10 ± 0.28; postoperative day 28 [1 M]: 1.04 ± 0.14; and postoperative day 112 [4 M]: 1.10 ± 0.34; $F = 2.463$, $P = .038$; Figure 3). The post hoc tests of the mean value indicated that the value on postoperative day 5 was significantly larger than that obtained preoperatively (CI: 0.14 to 0.35, $P = .025$). The HTPG for the operative side was not significantly different among the time points (preoperative: 1.08 ± 0.21; postoperative day 1: 1.13 ± 0.21; postoperative day 5: 1.09 ± 0.16; postoperative day 8: 1.11 ± 0.12; postoperative day 28: 1.10 ± 0.11; postoperative day 112: 1.11 ± 0.10; $F = 0.231$, $P = .948$; Figure 4).

DISCUSSION

This is the first report investigating the temporal evolution of otolith function before and after ELSD for MD. The results of this study showed that the UP-SVV showed deviation to the unaffected side, that is, negative deviation, on a postoperative day 5 (gradual) and the deviation disappeared by postoperative day 8 (transient). Possible explanations for this were as follows: (1) surgical manipulation caused transient stimulation of the peripheral vestibular endo-organs in the operated side and (2) surgical drainage caused right-left imbalance due to gradual functional improvement on the peripheral vestibular endo-organs in the operated side.

The first possibility is discussed in this paragraph. In the present study, the postoperative deviation of vertical recognition to the unaffected side recovered within 8 days after ELSD. To date, no previous report has described the changes in UP-SVV after ELSD, but studies

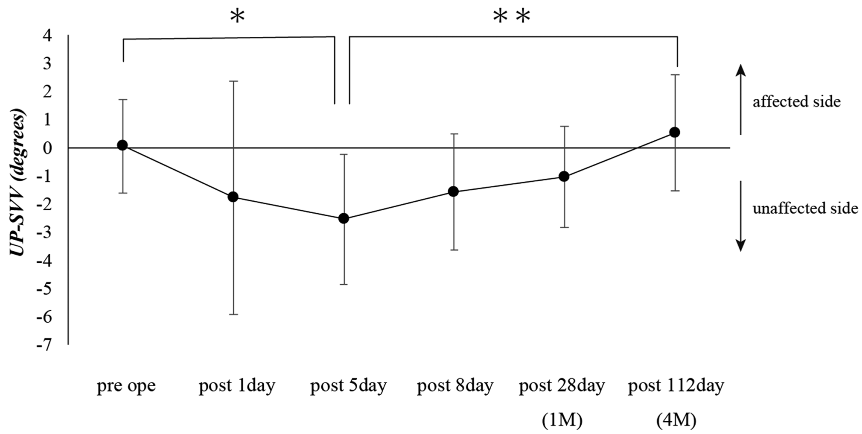

Figure 2. Changes in the deviation of UP-SVV after the operation. Positive values indicate deviations from the vertical to the affected side, and negative values indicate deviations in the direction of the unaffected side. The value on postoperative day 5 was significantly smaller than those obtained preoperatively and on postoperative day 112 (4 M). Pre ope indicates preoperatively. Post 1 day, 5 days, 8 days, 28 days (1 M), and 112 days (4 M) indicate postoperative days 1, 5, 8, 28 (1 M), and 112 (4 M). *$P < .05$, **$P < .01$, Tukey–Kramer method. UP-SVV, upright subjective visual vertical test.

have reported the corresponding changes after peripheral vestibular deafferentation procedures, such as vestibular neurectomy and labyrinthectomy.[17,23] After surgical vestibular deafferentation, all patients show a large deviation of UP-SVV to the operated side, and the deviation lasts for several months. In some cases, the deviation lasts for more than a year. Kumagami et al. noted that MD patients do not show UP-SVV deviations under normal circumstances, but during an attack, the deviations are larger, and most of the deviations are to the affected side.[24] The cases showing UP-SVV deviations toward the healthy side have nystagmus toward the affected side. The ELSD procedure in this study involved filling the endolymphatic sac with high concentrations of steroids, and spontaneous nystagmus toward the operated side appeared immediately after surgery.[25] Taken together, the findings suggest that the transient negative deviation of UP-SVV around postoperative day 5 could be influenced by the transient stimulation of the peripheral vestibule.

With respect to the second possibility, the present study showed no change in the UP-SVV on the first postoperative day, but it had deviated to the unaffected side on the fifth postoperative day. Ulubil et al. reported that approximately 20% of the cases showed improvement in caloric responses after endolymphatic sac surgery in comparison with the preoperative data.[13] Taken together, the gradual improvement in otolith function due to drainage by ELSD could be the reason for the subsequent negative deviation of UP-SVV.

Eight days after surgery, the negative deviation recovered gradually to the normal range. The deviation of UP-SVV after vestibular neuritis has been reported to normalize in accordance with the processes of vestibular compensation.[26] Many cases of these deviations improve to the normal range after 3 months. In addition, the UP-SVV of patients with MD not in the vertigo-attack phase is generally within the normal range. The results of UP-SVV could be consistent not only with vestibular otolithic function but also with graviceptive pathways, including the central nervous system.[23-27] In the present study, despite poorly controlled vertigo, the mean preoperative UP-SVV was 0.05° ± 1.66° and within the normal range, suggesting that the central nervous system could successfully compensate the right-left imbalance in the peripheral vestibular system before surgery. The therapeutic effects of ELSD and the subsequent otolithic functional imbalance could cause a gradual deviation of the UP-SVV to the unaffected side, resulting in the disappearance of the negative deviation due to vestibular compensatory re-adaptation in the central nervous system until postoperative day 8.

The average amount of deviation of UP-SVV on the fifth day in this study was 2.54° ± 2.31°, which was smaller than the 10°-30° deviation reported after peripheral surgical vestibular deafferentation

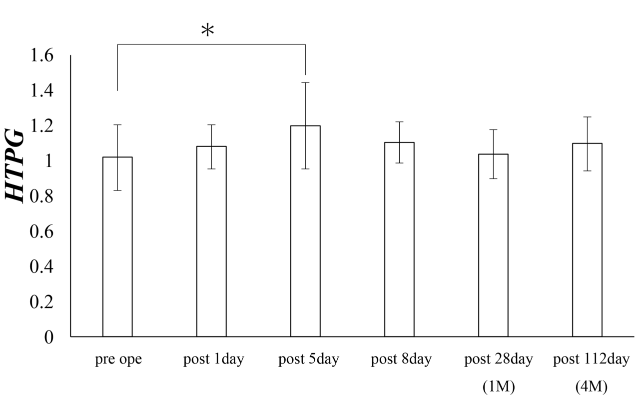

Figure 3. Changes in the HTPG for the unaffected side after surgery. The HTPG at postoperative day 5 was significantly larger than that obtained preoperatively. *$P < .05$, Tukey–Kramer method. HTPG, head-tilt perception gain.

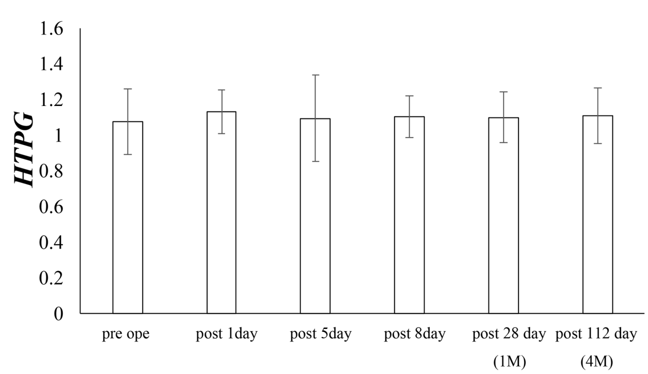

Figure 4. Changes in the HTPG for the affected side after surgery. The HTPG was always constant across time. HTPG, head-tilt perception gain.

procedures such as vestibular neurotomy.[17] The improvement in the deviation of the UP-SVV is correlated with improvement in body movement and floating sensation in postoperative vestibular neuritis and Wallenberg syndrome,[28,29] and the patients in this study could return to their daily life without any problem, since they did not complain of floating sensation by the eighth day. In comparison with vestibular disruption, ELSD, a vestibular function-sparing procedure, involves less risk associated with a postoperative floating sensation or impaired equilibrium.

The time course of the HTPG results showed no change at all time points in the affected side, while the unaffected side showed a significantly higher HTPG level on the fifth postoperative day, indicating a temporary overestimation of the tilt stimulus to the unaffected side. The HTPG was higher than 1 overall time course on both sides, indicating an E-effect with SVV bias to the opposite side. Since the deviation of UP-SVV and HTPG changes occurred in the same time course only on the unaffected side, it is possible that the changes might not be related to the surgical operation but may be associated with the changes in UP-SVV. All subjects have been moving with gait since postoperative day 1, suggesting that the increased sensitivity to tilt to the unaffected side may compensate for the postural instability caused by a deviation to the unaffected side of the UP-SVV. Vestibular compensatory processes observed after a vestibular disruption or vestibular neuritis are completed by enhancing cerebellar inhibition of the contralesional vestibular nuclei,[30] whereas vestibular function-sparing procedures such as ELSD could demonstrate different compensatory processes.

In this study, both UP-SVV and head tilt position SVV could be measured in all the patients from day 1 to day 112 (4 M) after surgery, and no side effects were observed. SVV is a less invasive test that requires only about 10 min even if the head tilt condition is performed additionally and is considered to be superior in that it is less burdensome on patients.

The present study had some limitations. First, it remains difficult to determine the main cause of postoperative changes in UP-SVV and HTPG results, the transient stimulation of the inner ear by surgical manipulation, and the gradual therapeutic effects of surgical drainage on the inner ear. Other neuro-otologic assessments such as measurement of vestibular evoked myogenic potentials and ocular counter-rolls should be performed to examine the detailed relationship between long-term changes in vestibular function and surgical outcomes from the viewpoint of vestibular compensatory processes. It was also necessary to examine the preoperative neuro-otologic assessment and the surgical changes in UP-SVV and HTPG, because the magnitude of the observed stimulation could be affected by preexisting damage. Second, the sample size was small, and it was not possible to correlate the changes in UP-SVV and HTPG results with the surgical improvement in vertigo. If we can increase the number of cases and correlate the extent of vertigo improvement and results of the endolymphatic hydrops test with the results of treatments other than ELSD, we will be able to determine the cause of the changes observed in the present study.

CONCLUSION

ELSD for MD is a surgical treatment that carries less risk of otolith function damage and abnormalities in gravitational cognition. SVV in the head-tilt position could be one of the neuro-otologic examinations used to easily understand the vestibular compensatory processes.

Ethics Committee Approval: The Medical Ethics Committee of Nara Medical University approved this study (certificate number: 916-5).

Informed Consent: All subjects provided written informed consent in accordance with the Declaration of Helsinki.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept –T.S., Y.W., T.K.; Design - T.S., Y.W.; Supervision - T.Y., T.K.; Resource - T.S., T.I.; Materials - T.S., Y.W.; Data Collection and/or Processing - T.S., Y.W.; Analysis and/or Interpretation - T.I.; Literature Search - T.S.; Writing - T.S.; Critical Reviews - T.I., T.K.

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Conflict of Interest: The authors have no conflict of interest to declare.

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