Otolith dysfunction in vestibular neuritis

Recovery pattern and a predictor of symptom recovery

H.-A. Kim, MD*
J.-H. Hong, MD*
H. Lee, MD
H.-A. Yi, MD
S.-R. Lee, MD
S.-Y. Lee, MD
B.-C. Jang, PhD
B.-H. Ahn, MD
R.W. Baloh, MD

Address correspondence and reprint requests to Dr. Hyung Lee, Department of Neurology, Keimyung University School of Medicine, 194 Dongsan dong, Daegu, 700-712 South Korea
hlee@dsmc.or.kr

ABSTRACT

Objectives: To prospectively follow patients with vestibular neuritis (VN), to compare the recovery pattern of canal and otolith dysfunction, and to determine which tests best predict symptom recovery.

Methods: Between March 2006 and December 2006, 51 consecutive patients with unilateral VN were enrolled within 7 days of onset (average 3 days). Otolith function tests included ocular torsion (OT), subjective visual vertical (SVV), and vestibular evoked myogenic potential (VEMP), and canal function tests included head-shaking nystagmus (HSN), caloric stimulation, and head-thrust testing. Patients returned for two follow-up evaluations at approximately 1 week and 6 weeks after the initial evaluation.

Results: On the first examination, all patients had abnormal HSN, caloric, and head-thrust test results, and at least one otolith-related test abnormality: abnormal tilt of SVV (48/51, 94%), abnormal OT (42/51, 82%), or abnormal VEMPs (25/51, 49%). The degree of SVV tilts correlated with the degree of OT for one or both eyes ($p < 0.05$). Skew deviation was observed in 7 patients (14%), and a complete ocular tilt reaction was detected in only 2 patients. On follow-up, otolith test results returned to normal more rapidly than canal test results. The head-thrust test was the best predictor of symptom recovery. Eighty percent of patients who continued to report dizziness at the last follow-up visit had a positive head-thrust test result, whereas only 10% of patients who were not dizzy had a positive head-thrust test result.

Conclusion: Otolith-related test abnormalities improve more rapidly than canal-related test abnormalities after vestibular neuritis. If patients have a positive head-thrust test result on follow-up, they are more likely to be dizzy. ***Neurology*® 2008;70:449–453**

GLOSSARY

CP = canal paresis; **CRb** = binocular cyclotorsion; **HSN** = head-shaking nystagmus; **n** = number of patients; **OT** = ocular torsion; **SCM** = sternocleidomastoid muscle; **SN** = spontaneous nystagmus; **SVV** = subjective visual vertical; **VEMP** = vestibular evoked myogenic potential; **VN** = vestibular neuritis; **VOG** = video-oculography.

Vestibular neuritis (VN) is a common neuro-otologic syndrome characterized by acute prolonged vertigo (lasting several days), nausea, and vomiting without other accompanying neurologic or audiologic symptoms or signs. It is commonly attributed to viral inflammation of the vestibular nerve and ganglion with a predilection for the superior branch of the nerve.[1] Most studies of vestibular dysfunction in VN have focused on the horizontal canal because caloric and head-thrust testing are readily available in the clinic.[2-5]

Some prior studies have described otolith-related dysfunction in VN,[6-11] but most were small in number,[6,8-11] included only a single measurement,[6,9-11] or did not show the recovery pattern of otolith dysfunction.[7,8] To the best of our knowledge, no large consecutive

*These two authors contributed equally to this work.

From the Department of Neurology (H.-A.K., J.-H.H., H.L., H.-A.Y.), Brain Research Institute (H.L., H.-A.Y., S.-R.L.), Ophthalmology (S.-Y.L.), Medical Genetic Engineering (B.-C.J.), and Department of Otorhinolaryngology (B.-H.A.), Keimyung University School of Medicine, Daegu, South Korea; and Department of Neurology and Division of Surgery (Head and Neck) (R.W.B.), UCLA School of Medicine, Los Angeles, CA.

Disclosure: The authors report no conflicts of interest.

clinical series has focused on the recovery pattern of the otolith and canal dysfunctions after VN.

METHODS Between March 2006 and December 2006, we identified 51 consecutive patients with acute unilateral VN from the Dizziness Clinics of Keimyung University Dongsan Medical Center (29 men, 22 women; mean age 59.3 years; age range 29 to 84 years). All patients met the clinical diagnostic criteria for VN, including sudden onset of prolonged vertigo (more than 1 day) with unidirectional spontaneous horizontal–torsional nystagmus, absence of other auditory or neurologic findings, reduced or absent caloric response, and no previous history of neuro-otologic diseases.[1]

MRI (Signa VH/i, General Electric, Milwaukee, WI), including diffusion-weighted images, was performed on all patients to exclude a central lesion mimicking peripheral vestibulopathy.

Patients were allowed symptomatic medication only when the autonomic symptoms were severe during the acute period and were encouraged to resume daily activities as soon as possible. None of the patients received a course of high-dose steroids[12] because it is unclear whether the risks of steroids outweigh the benefits in terms of symptom recovery. All experiments followed the tenets of the Declaration of Helsinki, and informed consent was obtained after the nature and possible consequences of the study had been explained to the participants.

Head-thrust testing was performed manually with rapid rotation of the head with approximately 20 ° amplitude in the yaw axis. A positive test result required corrective saccades after head thrusts toward the abnormal side observed by two different examiners (H.L., H.-A.K.).[13,14]

Video-oculography (VOG) (SMI, Teltow, Germany, resolution of 0.1 °, sampling rate of 60 Hz) was used to record spontaneous nystagmus (SN), head-shaking nystagmus (HSN), and caloric responses. HSN was induced by rotating the patient's head rapidly back and forth about the yaw axis at roughly 2 Hz and 30 ° amplitude. Caloric testing was performed with 30° C cold and 44° C warm air irrigations of each ear for 20 s. Asymmetry in caloric response was calculated using the Jongkees formula.

For the subjective visual vertical (SVV), the patients sat upright in a dark room with the head fixed using a head holder.[15] In front of the subject at a distance of 120 cm was a dim light bar, 2 mm wide and 90 cm long. The patients adjusted the bar to parallel alignment with the perceived gravitational vertical. The average of the 10 settings was used as the measure of the SVV. Detailed testing techniques have been previously published.[15]

An experienced neuro-ophthalmologist (S.-Y.L.) examined patients for skew deviation using a prism cover test, and then dilated the pupil and took a fundus photograph with the head upright to detect ocular torsion (OT). Position of the eye in the roll plane was determined as the angle between a straight line through the papilla and macula and the horizontal line. In addition to measuring the amount of torsion in each eye, we calculated the amount of binocular cyclotorsion (CRb), defined as the absolute value of the difference of cyclotorsion of both eyes: CRb = |cyclorotation of ipsilesional eye − cyclorotation of contralesional eye|. Excyclotropia was indicated as positive, and incyclotropia was indicated as negative.

Vestibular evoked myogenic potentials (VEMPs) were recorded in the sitting position from symmetric sites over the upper half of the sternocleidomastoid muscle (SCM) using bilateral surface electrodes, with a reference electrode on the upper edge of the sternum and a ground electrode on the forehead. During the recording, the patients were instructed to rotate their head to activate the SCM. The responses to 256 stimuli were averaged twice. To compare the amplitude of p13–n23 on the affected side (Aa) with that on the unaffected side (Au), the asymmetry ratio of each patient was calculated as $(Aa - Au)/(Aa + Au) \times 100$.[16]

The 51 patients were initially examined during the acute phase (average 3 days; range 0 to 7 days) after onset of vertigo and then scheduled for follow-up visits approximately 1 week and 6 weeks later. Forty-seven patients returned for the second examination (average 11 days; range 8 to 15 days after onset of vertigo), and 40 completed all three evaluations (average 47 days; range 27 to 57 days after onset of vertigo). A reference group consisted of 80 healthy age-matched volunteers (mean age 58.7 years; range 25 to 79 years) who had no vertigo or nystagmus and normal neurologic examination. VOG confirmed normal vestibular function in all members of the reference group (caloric asymmetry < 25%). Tests were considered abnormal if they were outside the average value ± 2 SDs (table 1).

A simple grading system of dizziness was used at follow-up: grade 1, no dizziness; grade 2, paroxysmal dizziness (intermittent, often triggered by head motion); grade 3, continuous dizziness (always by the same investigators: H.L., H.-A.K.).

Statistical analyses were performed by using the program SPSS (version 12.0; SPSS, Chicago, IL). Pearson correlations were used to describe the relationships between SVV and OT, and between SVV or OT and canal paresis (CP) on the first test. A χ^2 test was used to investigate the relationship between persistent dizziness and test results. We also used a paired *t* test to compare the degree of CP and the result of the head-thrust test. Significance was assumed at a value of $p < 0.05$.

RESULTS Acutely, all patients had SN, a positive head-thrust test result, and a significant caloric paresis (≥25% asymmetry). The degree of CP ranged from 38% to 100% (mean ± SD = 73 ± 20%) (table 1), and the intensity of SN ranged from 5 to 42 °/second (mean ± SD = 11 ± 7.2 °/second). In all patients, the fast phases of SN and HSN beat away from the side of the lesion. Head shaking augmented the SN in all patients.

Forty-two patients (82%) exhibited abnormal OT of one or both eyes (table 1). The mean OT of 51 patients was 14.6 ± 6.1 ° in the ipsilesional eye, 0.7 ± 7.2 ° in the contralesional eye, and 14.2 ± 11.9 ° on the both eyes (CRb). Skew deviation to the lesion side was observed in 7 patients (14%), and a complete ocular tilt reaction to the lesion side was observed in only 2 patients (4%).

Of the 51 patients, 48 (94%) showed abnormal tilts of the SVV to the lesion side (table 1). The mean SVV tilt of 51 patients was 6.8 ± 4.3 ° with

Table 1 Neurotologic findings in vestibular neuritis during the acute stage and at the last follow-up examination

	Frequency of abnormality on the first visit, n = 51	Frequency of abnormality on the last visit, n = 40
Vertigo	100%	0%
Dizziness	0%	50%
Persistent		10% (4/40)
Only during head motion		40% (16/40)
Canal-related dysfunctions		
SN*, mean ± SD	100%, 11 ± 7.2 °/s (range 5–42 °/s)	15%, 0.4 ± 0.9 °/s (range 0.3–3 °/s)
Positive head-thrust test result	100%	45%
Canal paresis, mean ± SD	100%, 73 ± 20% (range 38–100%)	78%, 51 ± 34.5% (range 0–100%)
HSN, mean ± SD	100%, 21 ± 8.9 °/s (range 15–67 °/s)	80%, 6.7 ± 2.5 °/s (range 3.7–10.5 °/s)
Otolith-related dysfunctions		
Type of abnormal OT	82% (42/51)	25% (10/40)
Both excyclotropia of ipsilesional eye and incyclotropia of contralesional eye	43% (22/51)	2.5% (1/40)
Only excyclotropia of ipsilesional eye	29% (15/51)	20% (8/40)
Only incyclotropia of contralesional eye	4.0% (2/51)	2.5% (1/40)
Only abnormal CRb	6.0% (3/51)	0% (0/40)
Skew deviation†	14% (7/51)	5.0% (2/40)
Head tilt†	4.0% (2/51)	0% (0/40)
Abnormal SVV tilts	94% (48/51)	25% (10/40)
Abnormal VEMPs†	49% (25/51)	15% (6/40)
Absence	22% (11/51)	5.0% (2/40)
Decreased amplitude	27% (14/51)	10% (4/40)

Normative data form our reference group: SVV tilts ≤ 2.0 °; OT, 0.5 to 11.5 ° (right), 0.5 to 12 ° (left), CRb ≤ 8 °; asymmetry of amplitude of VEMPs < 15%; caloric asymmetry < 25%; horizontal HSN < 3 °/second.

* Recorded without visual fixation by using video-oculography.

† To the ipsilesional side.

n = number of patients; SN = spontaneous nystagmus; HSN = head-shaking nystagmus; OT = ocular torsion; SVV = subjective visual vertical; CRb = binocular cyclotorsion; VEMP = vestibular evoked myogenic potential.

both eyes. In all patients with abnormal tilts of the SVV, the direction of SVV tilts was concordant with OT, and tilt angles of the OT were correlated with degrees of SVV tilts (Pearson correlation, $p < 0.05$). Six patients with abnormal SVV tilts showed no concurrent OT, but all patients with abnormal OT had abnormal tilts of SVV. The degree of CP was not correlated with tilt angles of SVV or OT (Pearson correlation, $p > 0.05$).

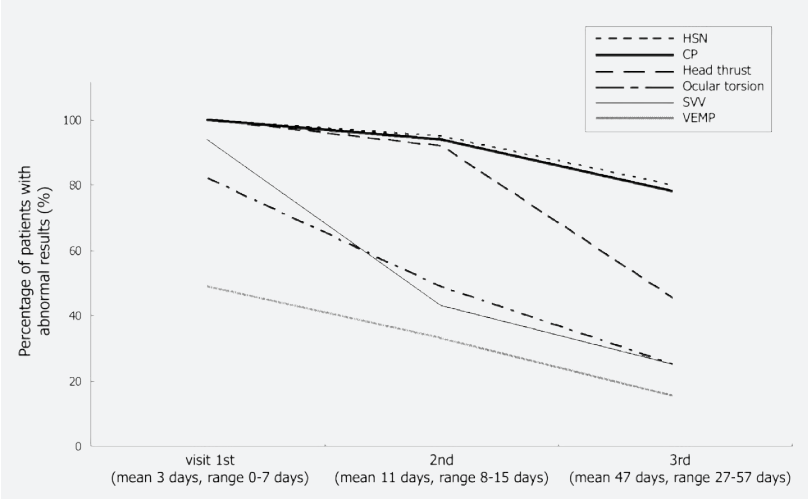
Abnormal VEMPs results were observed in 25 patients (49%). Decreased amplitude or absent VEMPs on the ipsilesional side were found in 14 and 11 patients, respectively.

Overall otolith-related abnormalities recovered more rapidly than canal-related abnormalities (table 1 and figure). HSN was the most persistent finding, still present in 80% of patients (32/40) at the last follow-up visit. Caloric CP persisted in 78% (31/40), and 45% (18/40) continued to have a positive head-thrust test result. At follow-up, patients with a persistent head-thrust abnormality had a greater CP on caloric testing than patients with a normal head-thrust test result ($p < 0.05$, paired t test). Abnormalities on OT, SVV, and VEMP were less persistent, being present in 25% or less of patients (table 1 and figure).

Only 8 patients (20%) had persistently abnormal ipsilesional deviation of SVV, and the tilt angles were mostly small (mean ± SD = 3.0 ± 1.3 °). Two patients showed abnormal contralesional tilts on SVV testing. Only 6 (15%) had persistently abnormal VEMPs (absent, n = 2; decreased amplitude, n = 4).

At the last follow-up visit, all patients showed marked improvement in their symptoms. None had vertigo, but half continued to report dizziness (paroxysmal dizziness [16/40, 40%] or continuous dizziness [4/40, 10%]). The other half were not dizzy (complete recovery) within 2 months of onset. Patients with persistent dizziness (paroxysmal and continuous combined) were significantly more likely to have a persistent positive head-

Figure Temporal evolution of canal-related (positive head-thrust sign, CP, and HSN) and otolith-related (SVV, OT, and VEMPs) vestibular dysfunctions after vestibular neuritis



CP = canal paresis; HSN = head-shaking nystagmus; SVV = subjective visual vertical; OT = ocular torsion; VEMP = vestibular evoked myogenic potential.

thrust test result and abnormal SVV compared with patients who were not dizzy (table 2). On the last follow-up, a positive head-thrust test result was the single best predictor of whether patients would have persistent dizziness. Eighty percent of patients who continued to report dizziness had a positive head-thrust test result, whereas only 10% of patients without dizziness had a positive head-thrust test result.

DISCUSSION Others have assessed canal[2-5] and otolith[6,9-11] function during recovery from VN, but this is the first prospective study comparing a battery of canal and otolith tests during recovery from VN. Acutely, by definition, all had a unilateral caloric paresis, but also all had SN, HSN, a positive head-thrust test result, and at least one otolith-related abnormality. Surprisingly, 49% had abnormal VEMPs, indicating that approximately half of patients with acute VN had involvement of the inferior branch of the vestibular nerve. Prior studies found a lower rate of inferior nerve involvement (up to 36%).[7-9]

Most patients had abnormal OT, but skew deviation and a complete ocular tilt response were infrequent. OT has not previously been systematically studied with VN. In our data, the degree of OT significantly correlated with the angle of tilts of SVV. However, it is unclear whether tilts of the SVV represent simply the sensory consequence of rotation of the eyes or the perceptual correlate of a vestibular tone imbalance in the roll plane. SVV tilts closely correlate with grade of lateropulsion in Wallenberg syndrome,[17] but the patients with VN who had large SVV tilts had only mild imbalance. Presumably, other sensory signals (visual and somatosensory) helped to compensate for the vestibular tone imbalance.

Overall during recovery from VN, otolith-related test results returned to normal more rapidly than canal-related test results. Test asymmetries after VN can be divided into two broad categories: dynamic (e.g., caloric, head thrust, HSN) and static (e.g., SN, OT, SVV). Symptoms and signs caused by static vestibular imbalance (e.g., vertigo, SN, OT, SVV) disappear more rapidly than those caused by dynamic vestibular imbalance, presumably because the central vestibular system can more easily compensate for static asymmetries than dynamic asymmetries.[18,19] Another possible explanation for the more rapid recovery of otolithic abnormalities with VN is that otolith-related pathways were less severely damaged than canal-related pathways. Therefore, central compensation or peripheral recovery of otolith vestibular imbalance may rapidly occur. Future studies that include dynamic otolithic vestibular tests might help to clarify this issue.

Interestingly, static asymmetries can even be overcompensated for in the recovery phase so that SN, OT, and SVV are transiently asymmetric in the reverse direction. On the other hand, the fact that nearly all VEMPs returned to normal may indicate that not only is the inferior branch of the vestibular nerve frequently spared, but when it is involved, it is involved to a lesser degree than the superior branch.

From the battery of canal and otolith tests, the head-thrust test was the best predictor of symptom recovery. This finding is consistent with a prior report[5] and probably means that a persistently positive head-thrust test result on follow-up indicates that the initial damage to the

Table 2 Test results in patients with and without dizziness at the final follow-up examination

	Dizziness, n = 20	No dizziness, n = 20	*p* Value*
Abnormal HSN†	90% (18/20)	70% (14/20)	0.114
Positive head-thrust test result	80% (16/20)	10% (2/20)	0.001
Abnormal caloric response	90% (18/20)	65% (13/20)	0.058
Abnormal SVV	40% (8/20)	10% (2/20)	0.028
Abnormal OT	25% (5/20)	25% (5/20)	1.000
Abnormal VEMPs	15% (3/20)	15% (3/20)	1.000

* Based on χ^2 test.
† Slow-phase velocity of induced nystagmus ≥ 3 °/second.
n = number of patients; HSN = head-shaking nystagmus; SVV = subjective visual vertical; OT = ocular torsion; VEMP = vestibular evoked myogenic potential.

vestibular nerve was severe and difficult to compensate for. Thus, the head-impulse test is a useful tool in assessing the degree of recovery after VN, in addition to its prognostic value. We did not attempt to quantify the severity of dizziness on follow-up because, for our purpose, we thought that the presence or absence of dizziness was a more easily and reliably measured endpoint. However, future studies will need to assess the quality and severity of dizziness during recovery from VN.

ACKNOWLEDGMENT

The authors thank H.-J. Yoon, PhD, an experienced statistician from Kyungbook University, for statistical assistance.

Received May 31, 2007. Accepted in final form July 19, 2007.

REFERENCES

1. Strupp M, Brandt T. Vestibular neuritis. Adv Otorhinolaryngol 1999;55:111–136.
2. Imate Y, Sekitani T. Vestibular compensation in vestibular neuronitis: long-term follow-up evaluation. Acta Otolaryngol 1993;113:463–465.
3. Okinaka Y, Sekitani T, Okazaki H, Miura M, Tahara T. Progress of caloric response of vestibular neuronitis. Acta Otolaryngol Suppl 1993;503: 18–22.
4. Bergenius J, Perols O. Vestibular neuritis: a follow-up study. Acta Otolaryngol 1999;119:895–899.
5. Nuti D, Mandala M, Broman AT, Zee DS. Acute vestibular neuritis: prognosis based upon bedside clinical tests (thrusts and heaves). Ann NY Acad Sci 2005;1039: 359–367.
6. Böhmer A, Rickenmann J. The subjective visual vertical as a clinical parameter of vestibular function in peripheral vestibular disease. J Vestib Res 1995;5:35–45.
7. Murofushi T, Halmagyi GM, Yavor RA, Colebatch JG. Absent vestibular evoked myogenic potentials in vestibular neurolabyrinthitis: an indicator of inferior vestibular nerve involvement? Arch Otolaryngol Head Neck Surg 1996;122:845–849.
8. Chen CW, Young YH, Wu CH. Vestibular neuritis: three-dimensional videonystagmography and vestibular evoked myogenic potential results. Acta Otolaryngol 2000;120:845–848.
9. Ochi K, Ohashi T, Watanabe S. Vestibular-evoked myogenic potential in patients with unilateral vestibular neuritis: abnormal VEMP and its recovery. J Laryngol Otol 2003;117:104–108.
10. Gomez Garcia A, Jaurequi-Renaud K. Subjective assessment of visual verticality in follow-up of patients with acute vestibular disease. Ear Nose Throat J 2003; 82:442–446.
11. Murofushi T, Iwasaki S, Ushio M. Recovery of vestibular evoked myogenic potentials after a vertigo attack due to vestibular neuritis. Acta Otolaryngologica 2006; 126:364–367.
12. Strupp M, Zingler VC, Arbusow V, et al. Methylprednisolone, valacyclovir, or the combination for vestibular neuritis. N Engl J Med 2004;351:354–361.
13. Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. Arch Neurol 1988;45:737–739.
14. Lee H, Sohn SI, Cho YW, et al. Cerebellar infarction presenting isolated vertigo: frequency and vascular topographical patterns. Neurology 2006;67:1178–1183.
15. Yi HA, Kim HA, Lee H, Baloh RW. Body lateropulsion as an isolated or predominant symptom of a pontine infarction. J Neurol Neurosurg Psychiatry 2007;4:372–374.
16. Welgampola MS, Colebatch JG. Characteristics and clinical applications of vestibular-evoked myogenic potentials. Neurology 2005;64:1682–1688.
17. Dieterich M, Brandt T. Wallenberg syndrome: lateropulsion, cyclorotation, and subjective visual vertical in thirty-six patients. Ann Neurol 1992;31:399–408.
18. Curthoys IS, Halmagyi GM. Vestibular compensation: a review of the oculomotor, neural, and clinical consequences of unilateral vestibular loss. J Vestib Res 1995; 5:67–107.
19. Choi KD, Oh SY, Kim HJ, Koo JW, Cho BM, Kim JS. Recovery of vestibular imbalances after vestibular neuritis. Laryngoscope 2007;117:1307–1312.