Dilatation of the Endolymphatic Space in the Ampulla of the Posterior Semicircular Canal: A New Clinical Finding Detected on Magnetic Resonance Imaging

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Objectives: To investigate the clinical features of ears with dilatation of the endolymphatic space in the ampulla of the posterior semicircular canal on magnetic resonance imaging.
Study Design: Retrospective study.
Setting: A university hospital.
Methods: This study included 1,842 ears from 934 patients who underwent 3-T magnetic resonance imaging with gadolinium to investigate the presence of endolymphatic hydrops. Age, sex distribution, hearing thresholds on pure-tone audiometry, and vestibular symptoms were compared between cases of unilateral and bilateral dilatation of the endolymphatic space in the ampulla of the posterior semicircular canal.
Results: Forty-eight ears (17 men and 14 women; mean age 49.9 yrs) showed dilatation of the endolymphatic space in the ampulla of the posterior semicircular canal. Age and the rate of chronic sensorineural hearing loss were significantly higher in the unilateral group (14 ears) than in the bilateral group (34 ears). The average hearing thresholds and rates of vestibular symptoms reported did not differ between unilateral and bilateral cases, but some patients showed positional nystagmus.
Conclusions: Dilatation of the endolymphatic space in the ampulla was observed selectively in the posterior semicircular canal, though its pathogenesis was not clear. Such dilatation is not usually accompanied by vestibular endolymphatic hydrops, and it may be a cause of vertigo and dizziness. **Key Words:** Ampulla—Magnetic resonance imaging—Posterior semicircular canal.

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Endolymphatic hydrops (EH) is defined as pathological distention of the endolymphatic spaces in the inner ear. Since the reports by Hallpike and Cairns (1) and Yamakawa (2), many histopathological studies of EH in the temporal bones of patients with Menière's disease (MD) have been performed (3,4).

Visualization of EH has become possible using 3-T contrast-enhanced magnetic resonance imaging (MRI) (5–7). Gurkov (8) and Sugimoto (9) investigated vestibular EH herniation into the semicircular canals (SCCs) on MRI. They reported that EH herniation was related to deterioration of caloric responses and hearing levels.

Occasionally, dilatation of the endolymphatic space in the ampulla of the posterior SCC is detected on MRI in patients who have vertigo or dizziness. Such dilatation is not normally observed even in ears with significant vestibular and/or cochlear EH. There has been no report of the clinical manifestations related to dilatation of the endolymphatic space in the ampulla of the posterior SCC, including histological studies in ears of patients with MD. In the present study, the focus was on the clinical manifestations related to such dilatation, and an attempt was made to identify the pathogenesis of this condition.

METHODS

The study included 1,842 ears from 934 patients (381 men and 553 women; age range, 11–90 yrs), who underwent MRI in our hospital to investigate the presence of EH between August 2013 and December 2018. Pure-tone audiometry was performed using an AA-79 diagnostic audiometer (Rion, Tokyo, Japan). Air- and bone-conduction thresholds were calculated for each ear at 250, 500, 1,000, 2,000, and 4,000 Hz.

Ears were evaluated by MRI performed 4 hours after intravenous injection of a standard dose (0.2 ml/kg body weight [i.e., 0.1 mmol/kg body weight]) of gadodiamide hydrate or 24 hours after intratympanic injection of gadopentetate dimeglumine diluted eightfold with saline, as described previously (5–7). All scans were performed using a 3-T MRI scanner (Trio or

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Verio; Siemens, Erlangen, Germany). A hybrid of reversed image of positive endolymph signal and native image of positive perilymph signal (HYDROPS) was used to identify EH (6,7). Radiologists who were blinded to the corresponding clinical information classified the degree of EH in the vestibule and cochlea into three grades (none, mild, and significant) according to the criteria described previously (10). The degrees of EH were measured by tracing the images, and cases that had significant enlargement of the endolymphatic space of the ampulla were identified on the basis of radiologists' readings. Representative images of the normal endolymphatic space in the ampulla of the posterior SCC are shown in Figure 1, and those of dilatation are shown in Figure 2.

Examination for positional nystagmus or video-oculography was performed in some patients with a long period of vertigo and dizziness or serious vestibular illness. The diagnosis of MD and delayed endolymphatic hydrops was made as described previously (11,12). Ears with the following conditions were excluded from the present study: an abnormal tympanic membrane, a previous medical history of otitis media, postoperative cases, and unavailable audiometric measurements.

Statistical analyses were conducted using SPSS IBM Statistics version 25 (IBM Corp., Armonk, NY). The Mann–Whitney *U* test was used to compare ages and hearing thresholds between groups. The χ^2 test was used to compare the sex distribution and the proportions among groups with unilateral or bilateral dilatation of the endolymphatic space. p values <0.05 were considered significant. All study protocols were approved by the ethics review committee of Nagoya University School of Medicine (approval number 2019-0067).

RESULTS

Of the 1,842 ears, 48 ears (24 men and 24 women; mean age 49.9 yrs) had dilatation of the endolymphatic space in the ampulla of the posterior SCC. Fourteen and 34 ears had unilateral and bilateral involvement, respectively. The demographic data of these ears are presented in Table 1. Their diagnoses were MD in 10 ears, fluctuating hearing loss in 5, acute sensorineural hearing loss (SNHL) in 5, chronic SNHL in 11, otosclerosis in 5, and 7 normal ears in patients with diseased contralateral ears (4 cases of MD and 3 cases of SNHL). The unilateral dilatation group had three MD cases (one case of unilateral MD and two cases of bilateral MD), and the bilateral dilatation group had seven MD cases (three cases of unilateral MD and four cases of bilateral MD). Otosclerosis cases were found only in the bilateral dilatation group.

When comparing ears with unilateral and bilateral dilatation of the endolymphatic space, the mean age

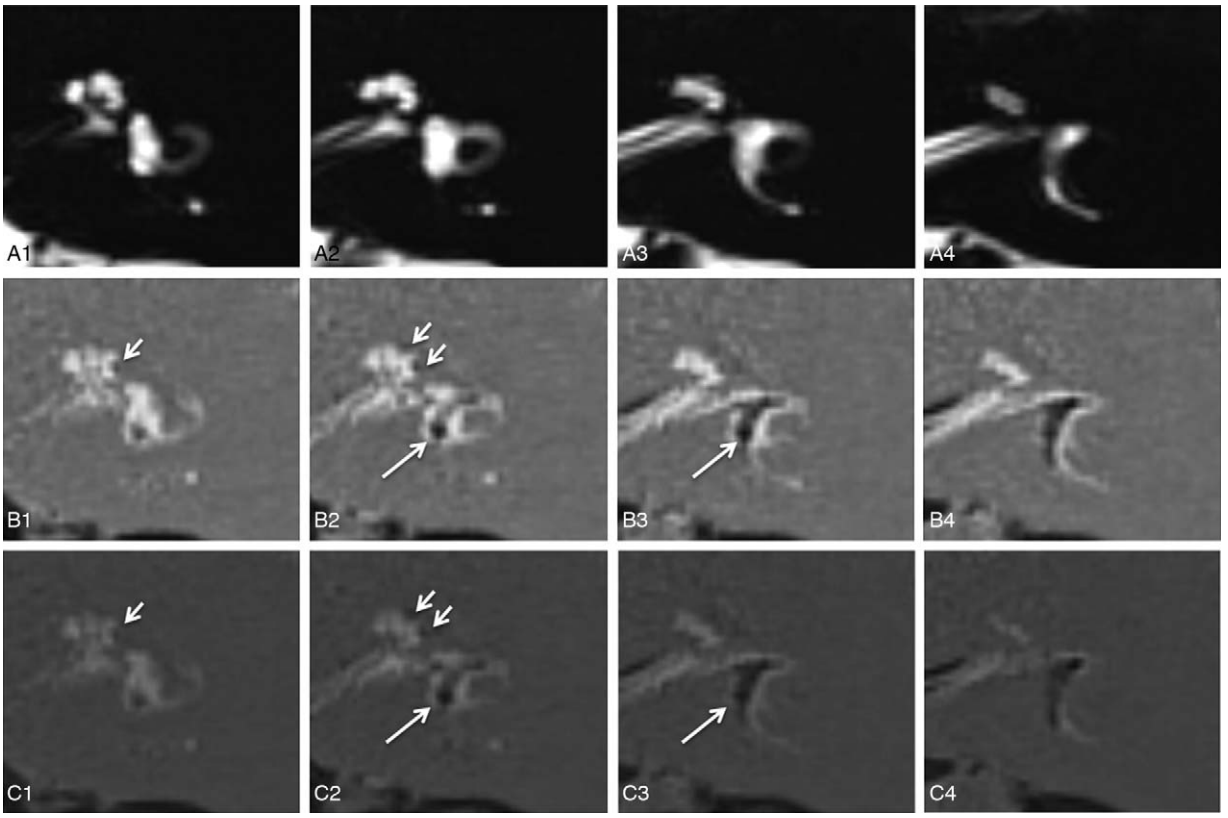

FIG. 1. Representative images of the normal endolymphatic space in the ampulla of the posterior semicircular canal (SCC). *A*, T2-weighted magnetic resonance cisternography is used to evaluate the anatomy of all fluid-filled labyrinth spaces. This image shows the regular anatomy of the vestibule and lateral SCC. *B*, T2-weighted three-dimensional Fluid Attenuated Inversion Recovery (3D-FLAIR) is used to visualize endolymphatic hydrops (EH). *C*, Hybrid of reversed image of positive endolymph signal and native image of positive perilymph signal (HYDROPS) is used to identify EH more clearly than T2-weighted 3D-FLAIR. The normal endolymphatic space in the ampulla is observed in the posterior SCC (black area in B2, C2, B3, and C3, the long *arrow*), and no vestibular EH is detected in (*B*) and (*C*). The short *arrows* show significant cochlear EH in B1, B2, C1, and C2.

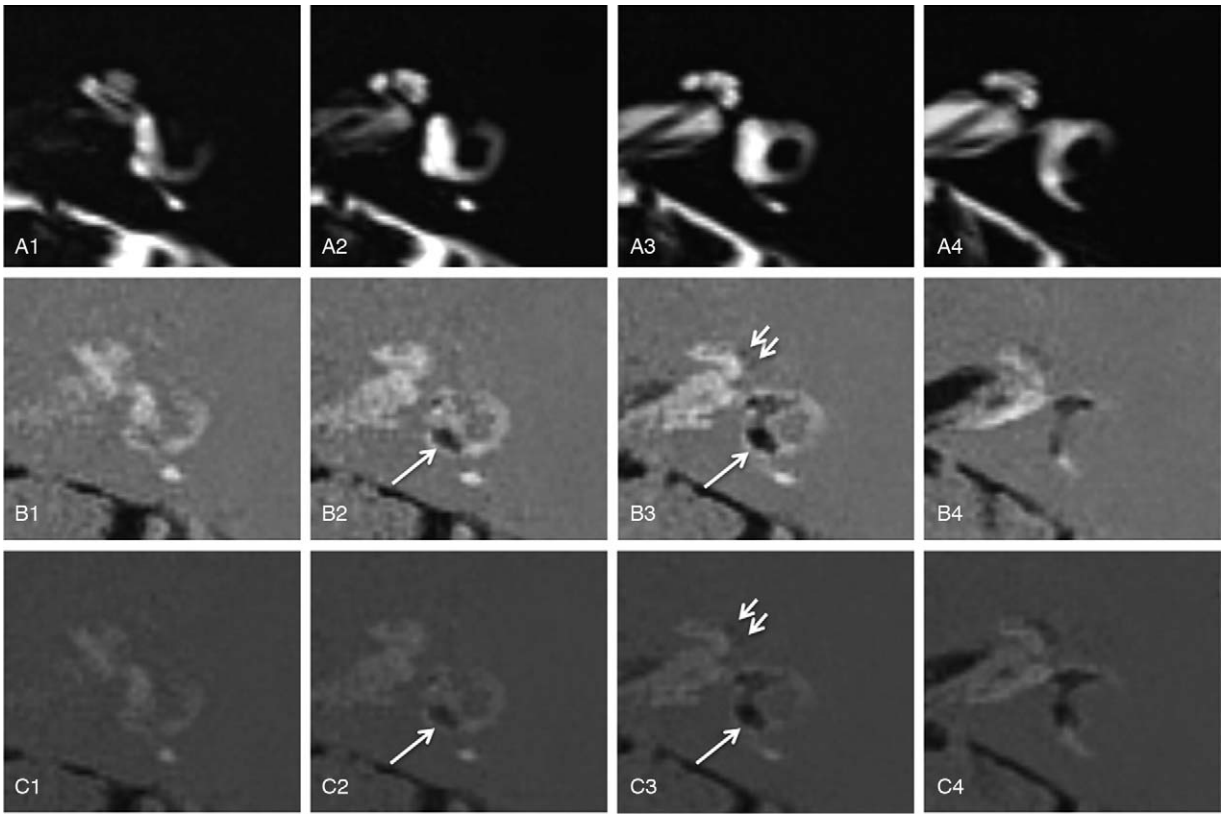

FIG. 2. Representative images of dilatation of the endolymphatic space in the ampulla of the posterior semicircular canal (SCC). *A*, T2-weighted magnetic resonance cisternography is used to evaluate the anatomy of all fluid-filled labyrinth spaces. This image shows the regular anatomy of the vestibule and lateral SCC. *B*, T2-weighted three-dimensional fluid attenuated inversion recovery (3D-FLAIR) is used to visualize endolymphatic hydrops (EH). *C*, Hybrid of reversed image of positive endolymph signal and native image of positive perilymph signal (HYDROPS) is used to identify EH more clearly than T2-weighted 3D-FLAIR. Dilatation of the endolymphatic space in the ampulla is observed in the posterior SCC (black area in B2, C2, B3, and C3, the long *arrow*), but no vestibular EH is detected in (*B*) and (*C*). The short *arrows* show significant cochlear EH in B3 and C3.

and rate of chronic SNHL were significantly higher in the unilateral group than in the bilateral group (57.6 versus 47.0 yrs, 42.9 versus 14.7%, respectively), but sex distribution, grades of cochlear or vestibular EH, and average hearing thresholds did not differ significantly between the groups. Acute SNHL and otosclerosis were only observed in the group with bilateral dilatation, but the difference was not significant.

Complaints of vertigo and/or dizziness were present in 23 of the 48 ears, with no significant difference between the groups. Six patients underwent further vestibular examinations, and four patients showed spontaneous or positional nystagmus, but there was no specific tendency. A representative case, which had bilateral dilatation of the endolymphatic space and showed upbeat positional nystagmus in the supine position, is shown in Figure 3. When this patient's head was turned 45° to the left and right, more rapid upbeat nystagmus with a rightward component was induced. There was no latency or fatigability. The air caloric test, cervical vestibular-evoked myogenic potential (cVEMP), and ocular vestibular-evoked myogenic potential (oVEMP) were evaluated. There was no significant difference between ears (canal paresis percentage on the air caloric test in the left ear: 7.1%, asymmetry ratio of cVEMP in the right ear: 29.5%, asymmetry ratio of oVEMP in the right ear: 5.9%). Another bilateral case showed positional left-beating nystagmus with latency when this patient's head was turned 45° to the left in the supine position. One unilateral case with right side dilation showed spontaneous right-beating nystagmus, which was aggravated when the patient's head was turned 45° to the right in the supine position. The other unilateral case with right side dilatation showed spontaneous downbeat nystagmus with a leftward component, which was aggravated when the patient's head was turned 45° to the left in the supine position.

DISCUSSION

EH has been a histologically characteristic finding in ears with MD (2–4), but recent advances in MRI evaluation enable visualization of EH in living persons, and many investigations including EH in SCCs have been reported (5–9,13–19). In the present study, the focus was on dilatation of the endolymphatic space in the ampulla of the posterior SCC, which has not been a systematically investigated lesion. Our preliminary study showed that almost all of the ears with such dilatation were limited to

TABLE 1. *Comparison between unilateral with bilateral dilatation of ampulla of posterior semicircular canal*

	Ears With Unilateral Dilatation of Ampulla of PSCC (n = 14)		Ears With Bilateral Dilatation of Ampulla of PSCC (n = 34)	
	Average	(SD)	Average	(SD)
Age (years)[a]	57.6	(13.9)	47.0	(13.9)
Sex (male/female)	6/8		18/16	
Grade of cochlear endolymphatic hydrops (no/mild/significant)	6/3/5		11/16/7	
Grade of vestibular endolymphatic hydrops (no/mild/significant)	10/2/2		25/4/5	
Vertigo and/or dizziness (%)	50.0		47.1	
Air conduction thresholds (dB HL)				
250 Hz	41.8	(30.2)	42.2	(27.9)
500 Hz	41.4	(34.9)	40.3	(30.5)
1000 Hz	43.2	(37.3)	36.6	(31.5)
2000 Hz	51.4	(37.5)	35.1	(31.8)
4000 Hz	52.5	(43.7)	34.9	(35.2)
Diagnosis (%)				
Menière's disease	21.4		20.6	
Delayed endolymphatic hydrops	7.1		0.0	
Fluctuating hearing loss	7.1		11.8	
Acute sensorineural hearing loss	0.0		14.7	
Chronic sensorineural hearing loss[a]	42.9		14.7	
Otosclerosis	0.0		14.7	
Floating sensation and aural fullness	0.0		5.9	
Large vestibular aqueduct syndrome	0.0		5.9	
Normal ears in patients with diseased contralateral ears	21.4		11.8	

[a] $p<0.05$.
SD indicates standard deviation.

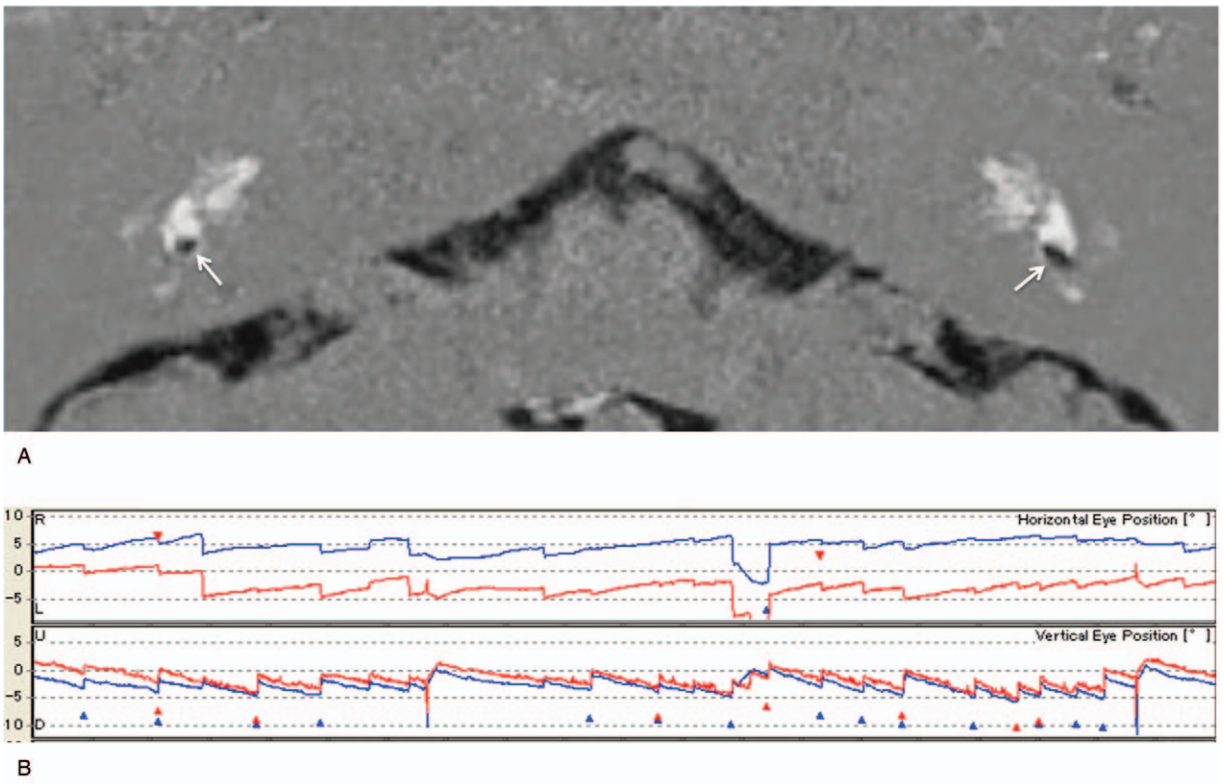

FIG. 3. A representative case with a complaint of vertigo. Hybrid of reversed image of positive endolymph signal and native image of positive perilymph signal (HYDROPS) images show bilateral dilatation of the ampulla of the posterior semicircular canal (*arrows* in (*A*)), which is prominent on the left side. The presence of upbeat nystagmus in the supine position is confirmed on video-oculography (*B*).

the posterior SCC, though the reason for such localization is unclear.

At one end of each SCC, a dilated sac called an ampulla exists. It consists of a thick gelatinous cap and many hair cells (20). MRI findings suggested that accumulation of endolymph caused dilatation of the endolymphatic space in the ampulla of the posterior SCC. There was no finding indicating a gelatinous ampulla. Anatomically, there is an utriculo-ampullar duct between the utricle and ampulla of the posterior SCC, which is not linear but distorted in temporal bone specimens (4,21). Constriction of the duct might cause poor endolymph flow from the ampulla to the utricle, which might develop to dilatation of the endolymphatic space in the ampulla of the posterior SCC. A short-armed BPPV (22), in which otoliths occur between the cupula of the ampulla of the posterior SCC and the utricle, may alter the endolymphatic flow toward the utricle and may cause the dilatation.

The rate of chronic SNHL was significantly higher in the unilateral group than in the bilateral group. Some factors that cause hearing loss may have led to the dilatation of the posterior SCC. Some patients showed spontaneous or positional nystagmus, but there was no specific tendency. The presence of vestibular EH was not frequent in ears with dilatation. The dilatation itself may affect the function of the crista ampulla and cupula in the lesion and may cause vertigo and dizziness.

Researchers may confuse dilatation of the endolymphatic space in the ampulla of the posterior SCC and vestibular EH herniation into the posterior SCC. An imaging finding of herniation into the posterior SCC detected on MRI is usually demonstrated as a sharp black area connected to the vestibule. Sugimoto et al. (9) reported that most ears with such herniation had severe cochlear and vestibular EH, and most of the herniations into the posterior SCC were located on the common crus side. Moreover, elevations of hearing thresholds and the degree of cochlear or vestibular EH are more prominent in ears with herniation than in those with dilatation.

There are some limitations in the present study, including the small number of ears investigated. Computed tomography examinations were not available to identify anomalies in the middle or inner ears for all ears. The video head impulse test, which could measure the function of the SCCs, was also not available in the present study. This study was a preliminary investigation of dilatation of the endolymphatic space in the ampulla of the posterior SCC. We are planning further studies to investigate the significance of such dilatation detected on MRI.

CONCLUSIONS

Dilatation of the endolymphatic space in the ampulla was observed selectively in the posterior SCC, though its pathogenesis is not clear. Such dilatation is not usually associated with vestibular EH, and it may represent a cause of another type of vertigo and dizziness.

REFERENCES

1. Hallpike CS, Cairns H. Observations on the pathology of Ménière's syndrome. *J Laryngol Otol* 1938;53:625–55.
2. Yamakawa K. Pathologic changes in a Meniere's patient. *J Otorhinolaryngol Soc Jpn* 1938;44:2310–2.
3. Fraysse BG, Alonso A, House WF. Meniere's disease and endolymphatic hydrops: Clinical-histopathological correlations. *Ann Otol Rhinol Laryngol* 1980;89 (6 pt 3):2–22.
4. Okuno T, Sando I. Localization, frequency, and severity of endolymphatic hydrops and the pathology of the labyrinthine membrane in Ménière's disease. *Ann Otol Rhinol Laryngol* 1987;96:438–45.
5. Nakashima T, Naganawa S, Sugiura M, et al. Visualization of endolymphatic hydrops in patients with Ménière's disease. *Laryngoscope* 2007;117:415–20.
6. Naganawa S, Yamazaki M, Kawai H, Bokura K, Sone M, Nakashima T. Imaging of Ménière's disease after intravenous administration of single-dose gadodiamide: utility of subtraction images with different inversion time. *Mag Res Med Sci* 2012;11:213–9.
7. Naganawa S, Nakashima T. Visualization of endolymphatic hydrops with MR imaging in patients with Ménière's disease and related pathologies: Current status of its methods and clinical significance. *Jap J Radiol* 2014;32:191–204.
8. Gurkov R, Flatz W, Louza J, et al. Herniation of the membranous labyrinth into the horizontal semicircular canal is correlated with impaired caloric response in Meniere's disease. *Otol Neurotol* 2012;33:1375–9.
9. Sugimoto S, Yoshida T, Teranishi M, et al. Significance of endolymphatic hydrops herniation into the semicircular canals detected on MRI. *Otol Neurotol* 2018;39:1229–34.
10. Nakashima T, Naganawa S, Pyykko I, et al. Grading of endolymphatic hydrops using magnetic resonance imaging. *Acta Otolaryngol Suppl* 2009;560:5–8.
11. Monsell EM, Balkany TA, Gates GA, et al. Committee on Hearing and Equilibrium guidelines for the diagnosis and evaluation of therapy in Meniere's disease. *Otolaryngol Head Neck Surg* 1995;113:181–5.
12. Kamei T. Delayed endolymphatic hydrops as a clinical entity. *Int Tinnitus J* 2004;10:137–43.
13. Pyykko? I, Nakashima T, Yoshida T, Zou J, Naganawa S. Ménière's disease: A reappraisal supported by a variable latency of symptoms and the MRI visualisation of endolymphatic hydrops. *BMJ Open* 2013;3:e001555.
14. Gu X, Fang ZM, Liu Y, Huang ZW, Zhang R, Chen X. Diagnostic advantages of intratympanically gadolinium contrast-enhanced magnetic resonance imaging in patients with bilateral Ménière's disease. *Am J Otolaryngol* 2015;36:67–73.
15. Mukaida T, Sone M, Yoshida T, et al. Magnetic resonance imaging evaluation of endolymphatic hydrops in cases with otosclerosis. *Otol Neurotol* 2015;36:1146–50.
16. Sone M, Yoshida T, Morimoto K, et al. Endolymphatic hydrops in superior canal dehiscence and large vestibular aqueduct syndromes. *Laryngoscope* 2016;126:1446–50.
17. Okazaki Y, Yoshida T, Sugimoto S, et al. Significance of endolymphatic hydrops in ears with unilateral sensorineural hearing loss. *Otol Neurotol* 2017;38:1076–80.
18. Yoshida T, Sugimoto S, Teranishi M, et al. Imaging of the endolymphatic space in patients with Meniere's disease. *Auris Nasus Larynx* 2018;45:33–8.
19. Morimoto K, Yoshida T, Sugiura S, et al. Endolymphatic hydrops in patients with unilateral and bilateral Meniere's disease. *Acta Otolaryngol* 2017;137:23–8.
20. Saladin, KS. Anatomy and Physiology. The Unity of Form and Function. New York: McGraw Hill. pp. 607–8.
21. Schuknecht HF. Rationale of surgical procedures for Menieré's disease. In: V osten KH, Schuknecht HF, Pfaltz CR, editors. et al. *Menieré's Disease*. Stuttgart: Georg Thieme Verlag; 198.]pp. 236–42.
22. Oas JG. Benign paroxysmal positional vertigo. A clinician's peespective. *Ann N Y Acad Sci* 2001;942:201–9.