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MAJOR PAPER

Imaging Endolymphatic Hydrops at 3 Tesla Using 3D-FLAIR with Intratympanic Gd-DTPA Administration

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Purpose: Visualization of endolymphatic hydrops by 3-dimensional fluid-attenuated inversion recovery-FLAIR using conventional turbo-spin-echo (3D-FLAIR-CONV) after intratympanic injection of Gd-DTPA has been reported in patients with Ménière's disease. Compared to 3D-FLAIR-CONV used in previous studies, the addition of a variable flip-angle technique (3D-FLAIR-VFL) enables very long echo trains and, therefore, shorter scan times. We evaluated whether 3D-FLAIR-VFL could replace 3D-FLAIR-CONV in detecting endolymphatic hydrops after intratympanic Gd-DTPA administration.

Methods: Eleven patients were included in this study. Twenty-four hours after Gd-DTPA injection, we performed 3D-FLAIR-CONV and 3D-FLAIR-VFL imaging at 3T. We compared the contrast-to-noise ratio (CNR) between cochlear fluid and the cerebellum between the 2 FLAIR sequences. We subjectively scored the size of the endolymphatic space in the cochlea and vestibule for each patient and correlated the scores with the clinical diagnoses.

Results: The CNR of 3D-FLAIR-CONV was significantly higher than that of 3D-FLAIR-VFL. Scores for the size of endolymphatic space in the vestibule were identical between the 2 sequences; however, those in the cochlea disagreed in 3 cases. 3D-FLAIR-CONV correlated better with the clinical diagnoses.

Conclusions: Currently, we may not be able to replace 3D-FLAIR-CONV with 3D-FLAIR-VFL, at least not with the scanning parameters used in the present study.

Keywords: *3D imaging, advanced imaging techniques, magnetic resonance imaging, temporal bone disease*

Introduction

Visualization of endolymphatic hydrops by magnetic resonance (MR) imaging after intratympanic injection of gadolinium-diethylene-triamine pentaacetic acid (Gd-DTPA) has recently been reported in patients with Ménière's disease. In these patients, on 3-dimensional fluid-attenuated inversion recovery (3D-FLAIR) obtained with a conventional turbo spin-echo sequence after intratympanic injection of Gd-DTPA at 3T, the enlarged endolymphatic space without Gd-DTPA distribution has been recognized as an area of low signal intensity partly surrounded by high-signal perilymphatic fluid with Gd-DTPA distribution.[1] Although the in-plane resolution was relatively high at 0.42 mm × 0.42 mm, the scan time was rather long, 15 min, even when applying a parallel imaging technique and utilizing slices 2-mm thick.

On the other hand, 3D-FLAIR covering the entire labyrinth can be obtained in 5 to 6 min with a near isotropic resolution of 0.67 mm × 0.67 mm × 0.8 mm by using a variable flip-angle turbo-spin-echo (3D-FLAIR-VFL) technique.[2] This voxel volume is almost identical to that of the conventional turbo-spin-echo 3D-FLAIR (3D-FLAIR-CONV) used in previous studies.[1,3] The shorter scan time of 3D-FLAIR-VFL enables its routine use in clinical settings. Thus, 3D-FLAIR-VFL has been used to evaluate various inner ear disorders.[4–10] The pre-contrast 3D-FLAIR-VFL scan was used to detect subtle changes in labyrinthine fluid composition, and the post-contrast 3D-FLAIR-VFL scan

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(following intravenous Gd-DTPA administration) was used to detect disruption of the blood labyrinthine barrier.[4,8]

We evaluated whether 3D-FLAIR-VFL could replace 3D-FLAIR-CONV for detecting endolymphatic hydrops after intratympanic Gd-DTPA administration.

Materials and Methods

Patients

Eleven patients (5 men, 6 women, aged 24–74; eight with clinically diagnosed Ménière's disease, one with sudden sensorineural hearing loss, one with fluctuating sensorineural hearing loss, and one with delayed endolymphatic contralateral-type hydrops) underwent intratympatic administration of gadolinium-diethylene-triamine pentaacetic acid-bis (methylamide) (Gd-DTPA-BMA; Omniscan, Daiichi-Sankyo Pharmaceutical Co. Ltd., Tokyo, Japan). These patients were scheduled for intratympanic injection therapy with gentamicin or, for the patient with sudden sensorineural hearing loss, a steroid. Written informed consent was obtained from all patients. This study was approved by the institutional review board of our university hospital.

Intratympanic gadolinium injection

The detailed methods for intratympanic gadolinium injection have been reported.[1] In that study, a delay of 24 hours between the intratympanic gadolinium injection and MR imaging was found to be optimal to allow the gadolinium to distribute widely in the perilymphatic space of the labyrinth.

Gd-DTPA-BMA was diluted 8-fold with saline (v/v 1:7) and injected intratympanically using a 23-G needle and a 1-mL syringe after the patient was placed in the supine position with head turned approximately 30° away from the sagittal line toward the healthy ear. The diluted Gd-DTPA-BMA was injected until a backflow of fluid into the external ear was observed through a microscope, resulting in an injected volume of 0.4 to 0.5 mL per patient. After the injection, the patient remained in the supine position for 60 min with head turned approximately 60° away from the sagittal line toward the healthy ear. Gentamicin or steroid was not injected at the same time.

MR imaging

All scans were performed on a 3T MR imaging scanner (MAGNETOM Trio, Siemens Medical Solutions; Erlangen, Germany) using a receive-only, 12-channel, phased-array coil. T_1-weighted 3D-FLASH (fast low-angle shot) and 3D-FLAIR-CONV images were acquired 24 hours after intratympanic injection of diluted Gd-DTPA-BMA.

In addition, T_2-weighted 3D-CISS (constructive interference in the steady state) imaging was performed to obtain reference images of the labyrinthine fluid-space anatomy.

The parameters for 3D-FLASH were: repetition time (TR), 4.3 ms; echo time (TE), 1.97 ms; flip angle, 10 degrees with radiofrequency (RF) spoiling; matrix size, 256 × 256; 96 axial 0.8-mm-thick slices covering the posterior fossa with a 16-cm^2 field of view (FOV); and number of excitations (NEX), 2. Total scan time was 2 min 51 s.

The parameters for 3D-CISS were: TR, 11.42 ms; TE, 5.71 ms; flip angle, 50 degrees; matrix size, 320 × 320; 48 axial 0.8-mm-thick slices; FOV, 16 cm^2; and NEX, 1. Scan time was 3 min 42 s.

The parameters for 3D-FLAIR-CONV were: TR, 9000 ms; TE, 128 ms; flip angle, 180 degrees (constant) for the turbo-spin-echo refocusing echo train; echo-train length, 23; matrix size, 384 × 384; 12 axial 2-mm-thick slices covering the labyrinth; FOV, 16 cm^2, acquired using the generalized autocalibrating partially parallel acquisition (GRAPPA) technique with an acceleration factor of 2;[11] and NEX, 1. The scan time was 15 min.

The parameters for 3D-FLAIR-VFL were: TR, 9000 ms; effective TE, 638 ms; variable flip-angle echo train with an average flip angle, 151 degrees; echo-train length, 171; matrix size, 384 × 384; 48 axial 0.8-mm-thick slices covering the labyrinth; FOV, 25.6 cm^2; acceleration factor, 2 using the GRAPPA technique;[11] voxel size, 0.67 mm × 0.67 mm × 0.8 mm; and NEX, 2. The total scan time was 5 min 26 s. The readout bandwidth was 592 Hz/pixel, and the echo spacing was 3.64 ms. Nonselective inversion pulses and slab-selective excitation pulses were used. The features of this variable flip-angle sequence have been reported elsewhere.[12–14] This sequence allows the use of very long echo-train lengths, in the range of 150 to 220, without severe blurring and while maintaining contrast similar to that of 3D-FLAIR-CONV, even with a long effective echo time. To achieve short echo spacing, field of view was larger than with other sequences.

Image evaluation

Qualitative evaluation

The size of the endolymphatic space in the vestibule was scored subjectively: a score of 3 indicated that the entire vestibule was occupied by endolymph; 2, more than half was occupied by endolymph; 1, from 30 to 50% was occupied by endo-

lymph; and 0, less than 30% was occupied by endolymph.

The size of endolymphatic space in the cochlear basal turn was scored subjectively: 3: the cochlear duct was larger than the perilymphatic space of the scala vestibule; 2: Reissner's membrane was bulging toward the scala vestibuli, though smaller than the perilymphatic space of the scala vestibule; 1: no bulging of Reissner's membrane; and 0: bulging of Reissner's membrane toward the scala media or no visualization of endolymphatic space. Two radiologists independently scored the size of the endolymphatic space. 3D-FLAIR-CONV and 3D-FLAIR-VFL were evaluated separately with an interval of 7 days. If a discrepancy existed between the two, consensus was obtained after discussion.

The probability of endolymphatic hydrops was scored tentatively from clinical records: 3, high; 2, moderate; 1, slight; and 0, low. This probability was scored subjectively based on the ratio of the summating potential to the action potential (SP/AP) on an electrocochleogram,[15,16] the vestibular evoked myogenic potential (VEMP),[17] audiogram frequency and fluctuation patterns, and clinical history. A positive VEMP response is considered to be a normal sign of vestibular function, especially for the saccule.[16] An SP/AP ratio larger than 36% is considered to be positive for cochlear endolymphatic hydrops.[16] However, because concrete diagnosis of endolymphatic hydrops is not possible, this probability score is not a perfect standard of reference.

Quantitative evaluation

The contrast-to-noise ratio (CNR) between the basal turn of the cochlea and the cerebellum was measured by drawing a circular region of interest (ROI) in the basal turn of the cochlea, in the cerebellum, and in air. The ROI diameter of the cochlea was 2 mm, and the ROI diameters of the cerebellum and air were 6 mm. The CNR value was defined as the difference in signal between the cochlea and cerebellum divided by the standard deviation of the air signal. CNR per scan time was defined as the CNR value divided by the square root of the scan time. CNR and CNR per scan time values were compared using student's t-test.

Results

No side effects related to the intratympanic injection were observed.

Table summarizes patients and evaluation results. On T_1-weighted 3D-FLASH, contrast enhancement in the labyrinth was quite faint in all patients; therefore, 3D-FLASH images were not used for further evaluation.

Image evaluation

Qualitative analysis

The scores for the size of the endolymphatic space in the vestibule were identical between the 2 sequences (Fig. 1). On the other hand, the scores for the size of the endolymphatic space in the cochlea disagreed in 3 cases (Fig. 2). In these 3 cases, 3D-FLAIR-VFL showed a score of 0 for the patients with a positive probability score.

Quantitative analysis

The CNR between the basal turn of the cochlea and the cerebellum was significantly higher with 3D-FLAIR-CONV (34.1 +/− 21.5) than with 3D-FLAIR-VFL (21.1 +/− 18.2) ($P<0.01$); however, CNR per scan time was not significantly different.

Discussion

Intratympanically injected Gd-DTPA is thought to be absorbed through round window membrane into labyrinthine space.[1] Gd-DTPA distributes mainly in the perilymph space, allowing separate visualization of the endo- and perilymph space.[1] A variable flip-angle turbo-spin-echo (VFL) sequence enabled the acquisition of images with a very long echo train (>100) and very long effective echo time (>300 ms) while keeping T_2-contrast and blurring at levels similar to that using a conventional turbo-spin-echo sequence with an echo train length of 15 to 30.[12,13]

A VFL sequence using a non-selective excitation pulse can image the whole brain with 1-mm isotropic resolution in a scan time of several minutes.[13] However, the 3D-FLAIR-VFL protocol employed in the present study used a slab-selective excitation pulse to reduce the imaged volume and scan time while obtaining sub-millimeter isotropic voxels.

This slab-selective 3D-FLAIR-VFL protocol can obtain images with a voxel volume comparable to that of 3D-FLAIR-CONV in a far shorter scan time. Scan time of 15 min by 3D-FLAIR-CONV is too long to include in routine practice in most hospitals. However, the CNR of cochlear fluid was significantly lower on 3D-FLAIR-VFL, and the in-plane acquisition spatial resolution was also lower. The effective in-plane resolution may be lower still as a result of blurring induced by the very long echo train, even though the variable flip-angle technique reduces blurring compared to a constant flip-angle echo train of the same length.

It might have been possible to compare reformatted 2-mm-thick 3D-FLAIR-VFL images made from 0.8-mm-thick data and 2-mm-thick 3D-FLAIR-

Table. Summary of patient's clinical and imaging results

age, gender	clinical diagnosis	side	hearing level	vertigo	SP/AP (%)	VEMP	contrast-to-noise ratio		size of endolymphatic space in cochlea			size of endolymphatic space in vestibule		
							3D-FLAIR-CONV	3D-FLAIR-VFL	3D-FLAIR-CONV	3D-FLAIR-VFL	probability of endolymphatic hydrops from clinical records	3D-FLAIR-CONV	3D-FLAIR-VFL	probability of endolymphatic hydrops from clinical records
46, M	Ménière's disease	left	60	yes	48%	noise	20	8.8	3	3	3	3	3	3
24, F	sudden deafness	right	68	yes	not recordable	bilateral response	25.3	11.3	0	0	0	0	0	0
55, F	Ménière's disease	left	58	yes	100%	noise	38.3	14.2	3	3	3	3	3	3
38, M	Ménière's disease	left	30	yes	38%	noise	9.7	7.8	3	3	3	3	3	3
69, M	Ménière's disease	left	32	yes	58%	noise	77.6	35.8	3	3	3	2	2	3
50, F	fluctuating hearing loss	right	13	no	19%	bilateral response	25.5	16	2	0	2	1	1	1
74, F	Ménière's disease	left	65	yes	60%	noise	38.3	21.7	3	3	3	2	2	3
44, F	vestibular Ménière's disease	left	10	yes	39%	bilateral response	29.2	17.1	2	0	2	1	1	1
38, M	vestibular Ménière's disease	left	8	yes	24%	bilateral response	20.3	10.2	0	0	1	0	0	1
47, F	Ménière's disease	left	22	yes	22%	bilateral response	20.1	18.8	2	0	2	2	2	1
38, M	delayed endolymphatic hydrops contralateral type	left	65	yes	77%	noise level	70.7	70.5	3	3	3	3	3	3

SP/AP = summating potential/action potential on electrocochleography
VEMP = vestibular evoked myogenic potential
3D-FLAIR-CONV = 3-dimensional fluid-attenuated inversion recovery (FLAIR) using conventional turbo-spin-echo
3D-FLAIR-VFL = 3-dimensional fluid-attenuated inversion recovery (FLAIR) using variable flip-angle technique

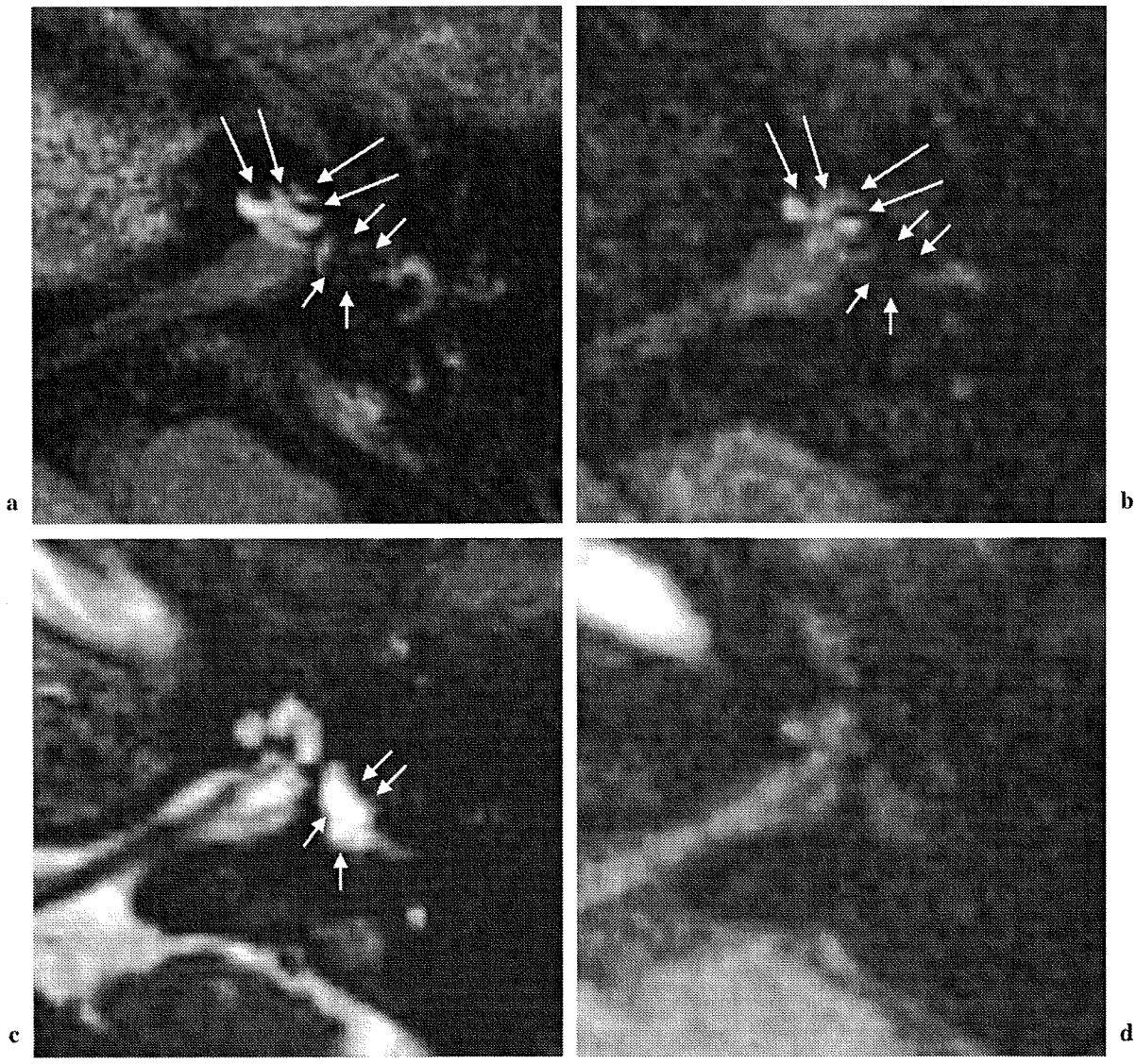

Fig. 1. A 46-year-old man with Ménière's disease. On both 3-dimensional fluid-attenuated inversion recovery using conventional turbo-spin-echo (3D-FLAIR-CONV) (**a**) and using variable flip-angle technique (3D-FLAIR-VFL) (**b**), the size of the endolymphatic space in the cochlea (arrows) and vestibule (short arrows) were scored as 3, although endolymphatic space in the cochlea is more clearly depicted on 3D-FLAIR-CONV. Almost no Gd-DPTA is seen in the vestibule in this case, whereas the vestibule is filled with lymphatic fluid on 3D- constructive interference in the steady state (CISS) (short arrows, **c**). On T_1-weighted 3D-fast low-angle shot (FLASH) (**d**), signal enhancement of perilymphatic fluid is quite faint; thus the discrimination between perilymph and endolymph is impossible.

CONV. However, increasing the reconstruction slice thickness of 3D-FLAIR-VFL would have resulted in the further degradation of the performance by 3D-FLAIR-VFL because the newly reconstructed voxel size of 3D-FLAIR-VFL was far larger than that of 3D-FLAIR-CONV.

The performance of 3D-FLAIR-VFL in detecting endolymphatic hydrops in the vestibule was comparable to that of 3D-FLAIR-CONV. In the cochlea, however, the 3D-FLAIR-CONV protocol was better, probably because of its higher in-plane resolution and higher CNR, as stated in the previous paragraph. The diameter of the cochlear duct (cochlear endolymphatic space) is smaller than the dimensions of the endolymphatic space in the vestibule, and the cochlear duct is in contact with surrounding bone tissue. Therefore, the recognition of endolymphatic hydrops in the cochlea might be more difficult than in the vestibule.

In the present study, we tried to reduce the scan time by a factor of 3 using 3D-FLAIR-VFL, which resulted in some image degradation. However, a

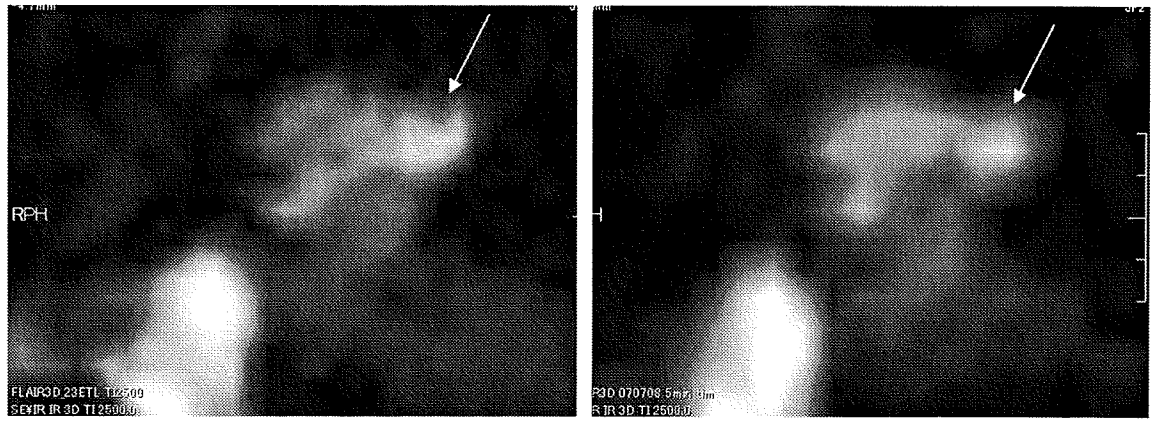

Fig. 2. A 50-year-old woman with fluctuating sensorineural hearing loss in the right ear. On 3-dimensional fluid-attenuated inversion recovery using conventional turbo-spin-echo (3D-FLAIR-CONV) (**a**), the size of endolymphatic space in the cochlea (arrow) was scored as 2; on 3D-FLAIR using variable flip-angle technique (VFL) (**b**), however, it was scored as 0 (arrow). This is probably due to the lower in-plane resolution and more blurring of 3D-FLAIR-VFL compared with 3D-FLAIR-CONV. The probability of endolymphatic hydrops from clinical records in cochlea was scored as 2.

factor-of-2 reduction, for example, might have been more practical. Further study is needed to determine a practical degree of scan time reduction.

The application of further technical developments also might improve the performance of 3D-FLAIR-VFL. For example, a T_2-selective inversion recovery scheme may provide a more time-efficient scan,[18] and the introduction of a 32-channel head array coil would improve the signal-to-noise ratio and thereby allow higher parallel imaging factors.[19]

In the present study, we reviewed the images only in the axial orientation. However, 3D-FLAIR-VFL had a higher spatial resolution in the z-direction than did 3D-FLAIR-CONV. The results might have been influenced if we had reviewed coronal or sagittal reformatted images, in addition to the original axial images.

One limitation of this study was the lack of a concrete standard of reference. We arrived at a tentative probability score for endolymphatic hydrops based not only on patient symptoms and history, but also on the results of objective tests such as the electrocochleogram and VEMP. However, it is difficult to evaluate the feasibility of using this score. In some cases, the results of the electorocochleogram and/or VEMP disagreed with clinical symptoms and disease history. The guidelines for Ménière's disease from the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) Committee of Hearing and Equilibrium define Ménière's disease mostly in terms of its symptoms,[20,21] describing the probability of the disease as *possible*, *probable*, *definite*, and *certain*. Certain Ménière's disease is defined as definite with histopathologic confirmation; objective diagnosis with histological confirmation is currently virtually impossible. To make the diagnosis of certain Ménière's disease in the future, MR imaging may be a desirable replacement for histological confirmation.

It would be very interesting if changes in 3D-FLAIR image findings were found to correlate with therapy-induced changes in the symptoms of endolymphatic hydrops. An individual longitudinal study might be useful to confirm the feasibility of this method in detecting and evaluating endolymphatic hydrops *in vivo*.

To compare the performance of 3D-FLAIR-VFL and 3D-FLAIR-CONV directly, a phantom simulating the actual dimensions of labyrinthine anatomy as well as the Gd-DTPA concentrations of labyrinthine endolymph and perilymph would also be helpful.

Conclusions

3D-FLAIR-VFL can obtain images with a voxel volume comparable to that of 3D-FLAIR-CONV and detect endolymphatic hydrops of the vestibule at a similar rate in a scan time that is nearly a factor of 3 shorter. However, the performance in detecting endolymphatic hydrops of the cochlea was lower with 3D-FLAIR-VFL. Thus, we currently may not be able to replace 3D-FLAIR-CONV with 3D-FLAIR-VFL, at least not with the scanning parameters used in the present study.

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Three-Dimensional Fluid-Attenuated Inversion Recovery Magnetic Resonance Imaging Findings and Prognosis in Sudden Sensorineural Hearing Loss

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Objectives/Hypothesis: Three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging (MRI) has recently been developed to detect high concentrations of protein or hemorrhage. We have previously reported that 50% of patients with sudden sensorineural hearing loss (SNHL) show high signals in the affected inner ear on 3D-FLAIR MRI. However, the relationship between 3D-FLAIR findings and hearing prognosis is unclear. Our objective was to evaluate the relationship between the results of 3D-FLAIR MRI at 3 Tesla and prognosis in sudden SNHL.

Study Design and Methods: We used 3D-FLAIR at 3 Tesla with and without gadolinium enhancement to evaluate the pathologic conditions in the inner ears of 48 patients with sudden SNHL.

Results: Thirty-one of 48 patients with sudden SNHL showed high signals in the affected inner ear on precontrast 3D-FLAIR. Hearing improvement in patients with high signals in the affected inner ear on precontrast 3D-FLAIR (25 ± 19 dB) was significantly worse than that in patients with no signal (45 ± 27 dB; $P < .05$). Our analysis suggests that high signals in the affected inner ear on precontrast 3D-FLAIR MRI is a new prognostic factor for sudden SNHL.

Conclusions: 3D-FLAIR findings show that high signals in the cochlea on precontrast 3D-FLAIR are related to a poor hearing prognosis. These signals may reflect minor hemorrhage or an increased concentration of protein in the inner ear, which has passed through blood vessels with increased permeability or has originated in disrupted cells in the inner ear.

Key Words: Fluid-attenuated inversion recovery, sudden sensorineural hearing loss, magnetic resonance imaging, prognosis.

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INTRODUCTION

The pathology of sudden sensorineural hearing loss (SNHL) remains unclear. The hypothesized pathologies include viral infection,[1] vascular compromise,[2] disruption of cochlear membranes,[2] inner ear anomaly,[3] and immunologic diseases.[1] However, no cause is found in most cases.

We have previously reported that four of eight patients with sudden SNHL showed high precontrast signals in the inner ear on three-dimensional fluid-attenuated inversion recovery (3D-FLAIR), and one of these four patients showed gadolinium (Gd) enhancement in the affected inner ear on 3D-FLAIR.[4] Furthermore, high signals in the affected inner ear are present in other inner ear diseases.[5–8] These signals may reflect minor hemorrhage or an increased concentration of protein in the inner ear, which has passed through blood vessels with increased permeability.[4] However, the relationship between 3D-FLAIR findings and clinical signs has not been clarified. We cannot make a prognosis for patients with sudden SNHL before treatment, although these patients wish to know the prognosis for sudden SNHL. In this study, we investigated the correlation between 3D-FLAIR findings and SNHL prognosis and between 3D-FLAIR findings and other clinical signs.

MATERIALS AND METHODS

Subjects

We evaluated 48 patients (24 men and 24 women; mean age ± standard deviation, 50.0 ± 16.4 yr) with unilateral sudden SNHL who visited Nagoya University Hospital between December 2005

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and July 2007. The criteria for sudden SNHL used in this study were that the patient could describe the day of onset of sudden SNHL, which had no obvious cause, and that no HL had been noted before the onset of SNHL. We excluded patients with fluctuating HL or progressive HL. All these patients were examined with T1- and T2-weighted magnetic resonance imaging (MRI) and 3D-FLAIR MRI before and after Gd enhancement. We also evaluated 11 patients at second and third examinations more than 3 months after onset using 3D-FLAIR MRI in a follow-up study. Eight patients, who had been reported in our previous study,[3] were included in this study. In all patients, hydrocortisone was administered intravenously 200 mg per day for 4 days and then 100 mg for 3 days with adenosine triphosphate (60 mg per day).

Audiologic Findings

Hearing levels were evaluated using an audiometer (Model AA-79S; Rion, Tokyo, Japan) in a sound-insulated chamber. The initial audiograms were obtained at the first visit, and the final audiograms were taken after 2 months had elapsed since the onset of deafness, except for patients who recovered completely within this period. Serial audiograms were compared with tympanograms and speech discrimination scores, when available. The average hearing level was expressed as the average score at three frequencies (500, 1,000, and 2,000 Hz). If the patient did not respond to the maximum sound level produced by the audiometer, we defined the threshold as 5 dB added to the maximum level.

The outcome of sudden SNHL was evaluated using the criteria of the Ministry of Health and Welfare in Japan.[9] The average hearing level on these criteria was calculated as the mean of the hearing levels measured at 250, 500, 1,000, 2,000, and 4,000 Hz. Recovery was ranked as follows:[10] no change (improvement in hearing of less than 10 dB on average); slight improvement (improvement in hearing of 10 dB or more but less than 30 dB on average); remarkable improvement (improvement in hearing of 30 dB or more on average); and complete recovery (all 5 frequencies on the final audiogram were 20 dB or less or improvement to the same degree of hearing as in the contralateral ear). The prognosis score was assigned as follows: 0 = no change; 1 = slight improvement; and 2 = remarkable improvement or complete recovery.

The periods between the onset of HL and the MRI study were compared between patients with and without high signals on 3D-FLAIR. The average prognosis scores were compared between patients with and without high signals on 3D-FLAIR. All statistical analyses were performed using the Mann-Whitney U test or the χ^2 test.

A multivariate regression analysis was used to identify the prognostic factors that were related to the final audiograms. The following factors were examined as explanatory variables: age, sex, presence of vertigo at the onset of sudden SNHL, the period from onset of sudden SNHL to first visit, precontrast high signals in the inner ear on 3D-FLAIR, and the initial audiogram. The data were analyzed by multivariate regression using the SPSS 8.0 statistical package (SPSS, Inc., Chicago, IL).

MRI

All scans were performed at 3 Tesla MRI (Trio; Siemens, Erlangen, Germany) using a receive-only eight-channel phased-array coil. Before and after the intravenous administration of a single dose of Gd–diethylenetriaminepentaacetic acid–bis methylamide (Gd–DTPA–BMA; Omniscan; Daiichi Pharmaceutical Co., Ltd., Tokyo, Japan) at 0.1 mmol/kg, T1-weighted 3D fast low-angle shot (FLASH) imaging and 3D-FLAIR imaging were performed. Heavily T2-weighted 3D constructive interference in the steady state imaging was performed only before the contrast material was administered to delineate the anatomy of the cerebrospinal fluid space. 3D-FLAIR and 3D-FLASH images were obtained before and after the administration of a single dose of Gd–DTPA–BMA. After the contrast was administered, 3D-FLASH was scanned first. Then, contrast-enhanced 3D-FLAIR was initiated 7 minutes after the Gd was administered so that the contrast 3D-FLAIR images were determined approximately 10 minutes after the administration of the Gd. These methods have been described in detail in previous reports.[4,10–12]

MRI Findings

The MRI findings for the inner ear in patients with sudden SNHL were evaluated using our own criteria. MRI findings were ranked as follows: none (no signal in the affected inner ear); faint (the signals in the affected inner ear were higher than those of the cerebrospinal fluid but lower than those of the cerebellar white matter); moderately high (the signals in the affected inner ear were as high as those of the cerebellar white matter); and very high (the signals in affected inner ear were higher than those in the cerebellar white matter).

RESULTS

The characteristics of 48 patients with sudden SNHL are summarized in Table I. Thirty-one of the 48 patients with sudden SNHL showed high signals in the affected inner ear on precontrast 3D-FLAIR. Sixteen of these 31 patients also showed Gd enhancement on 3D-FLAIR in the affected inner ear. The high-signal areas observed on 3D-FLAIR were not detected by T1- or heavily T2-weighted MRI in any of these patients. All patients had no signals in the unaffected inner ear. We could perform follow-up MRI study in 11 of 48 patients. In these patients, high signals in affected inner ears on precontrast or postcontrast 3D-FLAIR had disappeared after approximately 90 to 150 days from onset of sudden SNHL. Figure 1 shows a follow-up MRI finding of a patient with right sudden SNHL.

The average initial hearing level was 80 ± 17 dB in the group with high signals on precontrast 3D-FLAIR and 75 ± 19 dB in the group with no signals. There was no statistically significant difference in the initial hearing levels of the two groups (Mann-Whitney U test). However, hearing improvement in the high-signal group (25 ± 19 dB) was significantly worse than that in the no-signal group (45 ± 27 dB; $P < .01$; Mann-Whitney U test) (Fig. 2) (Table I).

A multivariate regression analysis of the audiologic assessment was made for all patients, which included age [a positive value of the β (normalized regression) coefficient indicates a better hearing prognosis in young patients], the presence of vertigo at the onset of sudden SNHL (a negative value of the β coefficient indicates that a lack of vertigo entails a better hearing prognosis than that of patients with vertigo), precontrast high signals in the inner ear on 3D-FLAIR (a positive value of the β coefficient indicates that a lack of high signals reflects a better hearing prognosis than the prognosis in the presence of high signals), the period from the onset of sudden SNHL to the first visit (a positive value of the β coefficient indicates a poorer hearing prognosis in patients who visited late), and initial audiogram (a positive value of the β coefficient indicates a poorer hearing prognosis in patients with a high level of initial HL). This analysis revealed that

TABLE I.
Patient Characteristics.

Characteristic	High Signals in the Cochlea Group	No Signal in the Cochlea Group	*P* Value
No. patients	31	17	
Age (yrs)	50.5 ± 17.7	49.3 ± 14.7	0.9
Sex (female/male)	17/14	6/11	0.19
Number of patients with vertigo	12	3	$P < 0.01$
Ear (right/left)	16/15	8/9	0.76
High signals in vestibule	10	1	$P < 0.01$
Gadolinium enhancement	16	0	$P < 0.01$
Initial audiogram (dB)	80 ± 17	75 ± 19	0.38
Final audiogram (dB)	55 ± 27	31 ± 21	$P < 0.01$
Period to initial visit	9 ± 8	5 ± 4	0.08
Period to MRI	15 ± 12	10 ± 8	0.08

High signal = high signal in the affected inner ear on precontrast three-dimensional fluid-attenuated inversion recovery (3D-FLAIR); High signals in vestibule = high signals in the vestibule on precontrast 3D-FLAIR; Gadolinium enhancement = gadolinium enhancement in the affected inner ear on postcontrast 3D-FLAIR; Period to initial visit = period from the onset of sudden sensorineural hearing loss to the initial visit; Period to MRI = period from the onset of sudden sensorineural hearing loss to magnetic resonance imaging.

the following factors were independently related to a worse hearing prognosis for patients with sudden SNHL: high signals in the affected inner ear on precontrast 3D-FLAIR, the period from the onset of sudden SNHL to the first visit, and the initial audiogram (Table II). The period between the MRI study and the onset of HL in patients with sudden SNHL did not differ significantly between patients with high signals (15 ± 12 d) and those with no signal (10 ± 8 d) (Mann-Whitney *U* test) (Table I).

Hearing improvement (24 ± 19 dB) in patients who showed Gd enhancement on 3D-FLAIR in the affected inner ear was not significantly different from that (36 ± 25 dB) in patients who did not (Mann-Whitney *U* test). On postcontrast 3D-FLAIR, three patients who had no signal on precontrast 3D-FLAIR showed Gd enhancement on 3D-FLAIR in the affected inner ear.

Ten patients showed high signals in both the cochlea and the vestibule on precontrast 3D-FLAIR in the affected ear, and 8 of these 10 patients suffered from vertigo at the onset of sudden SNHL. One patient showed high signals only in the vestibule, without high signals in the cochlea on precontrast 3D-FLAIR in the affected inner ear, and this patient suffered from vertigo at the onset of sudden SNHL. In this patient, 3D-FLAIR was performed 17 days after the onset of sudden SNHL. There was a relationship between the vertigo at the onset of sudden SNHL and high signals in the vestibule of the affected inner ear ($P < .05$; χ^2 test). Furthermore, the final hearing levels of patients with high signals in the vestibule were significantly worse than those of patients who did not have these high signals ($P < .05$; Mann-Whitney *U* test).

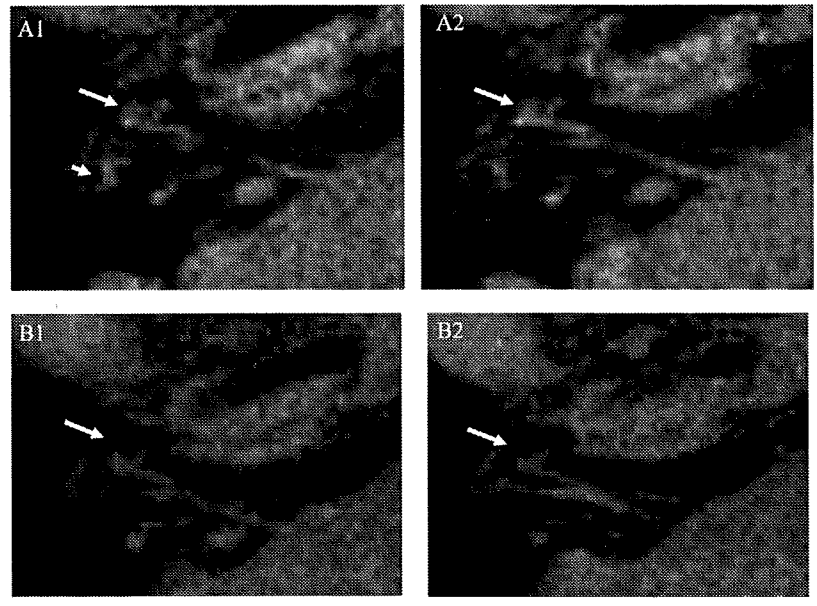

Fig. 1. Axial magnetic resonance image. Right inner ear of a 45-year-old man with vertigo and right sudden sensorineural hearing loss. (A1) First three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) image before enhancement. Bright signals are very high in right cochlea (long arrow) and vestibule (short arrow). (A2) First 3D-FLAIR image after enhancement. Gadolinium enhancement is not observed in right cochlea (long arrow). (B1) Second 3D-FLAIR image before enhancement. No bright signal is visible in right cochlea or vestibule. (B2) Second 3D-FLAIR image after enhancement. No gadolinium enhancement is visible in right cochlea.

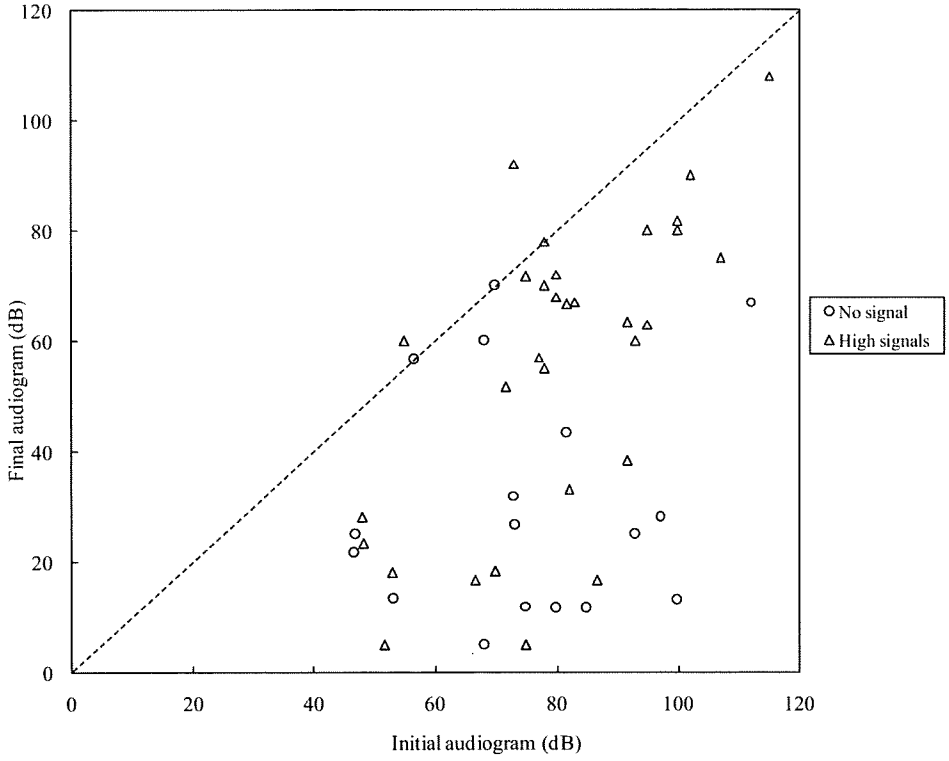

Fig. 2. Hearing improvement in patients with and without high signals in affected inner ear on precontrast three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging. Spots near transverse dotted line show bad prognoses for sudden sensorineural hearing loss (SNHL). Conversely, spots near bottom line show good prognoses for sudden SNHL. High signals in cochlea in affected ear on precontrast 3D-FLAIR suggest poor hearing prognosis in sudden SNHL.

DISCUSSION

The major finding of this study is that 3D-FLAIR findings are closely related to hearing prognosis in sudden SNHL. This is the first report to demonstrate that high signals in the cochleae of affected ears on precontrast 3D-FLAIR suggest poor hearing prognoses in sudden SNHL. We have previously reported that four of eight patients with sudden SNHL showed high signals in the inner ear on precontrast 3D-FLAIR and that one of these four patients showed Gd enhancement in the affected inner ear on 3D-FLAIR.[4] However, in that study, our data were insufficient to evaluate the relationship between the 3D-FLAIR findings and hearing prognosis. It demonstrated that 3D-FLAIR is a very useful tool with which to predict the prognosis before treatment.

In this study, we have shown the possibility of identifying poor prognostic factors with 3D-FLAIR. The prognostic factors for sudden SNHL reported previously include age,[13] male sex,[14] the type of audiogram,[13] the level of HL,[14] tinnitus and vertigo,[14] the method of treatment,[13] and the time of treatment initiation.[13] However, the relationship between the hearing prognosis and the imaging findings is not clear. Precontrast high signals on 3D-FLAIR may reflect minor hemorrhage or an increased concentration of protein in the inner ear, which has passed through blood vessels with increased permeability or has originated in disrupted cells in the inner ear. We have shown that precontrast high signals on 3D-FLAIR are independently related to hearing prognosis. Therefore, precontrast high signals on 3D-FLAIR may be a new prognostic factor in sudden SNHL.

Sudden SNHL is caused by a variety of unknown pathophysiologic mechanisms. To develop more effective therapies, it is necessary to understand more precisely the pathology of sudden SNHL. We have also shown an asso-

TABLE II.
Multivariate Regression Model of Impact on Final Audiogram.

Independent Variables	Values	β (Standard Regression Coefficient)	Standard Error	t	*P* Value
Age		0.158	0.19	1.38	0.174
Sex	1 = male, 0 = female	−0.005	6.34	−0.04	0.964
Vertigo	1 = yes, 0 = no	0.091	7.3	0.74	0.464
Period to initial visit		0.312	0.5	2.58	$P < 0.05$
High signals in the cochlea	1 = yes, 0 = no	0.248	7.3	2.07	$P < 0.05$
Initial audiogram		0.416	0.2	3.36	$P < 0.01$

$R^2 = 0.502$, adjusted $R^2 = 0.429$.
Period to initial visit = period from the onset of sudden sensorineural hearing loss to the initial visit; high signals in the cochlea = high signals in the cochlea on precontrast 3D-FLAIR.

ciation between 3D-FLAIR findings and clinical signs, especially those pertaining to vertigo. 3D-FLAIR MRI may be a key to resolving these problems. Therefore, it is possible that 3D-FLAIR MRI will provide made-to-order treatments for patients with sudden SNHL in the future. Further study is necessary to clarify the relationship between MRI findings and the efficiency of several treatments to develop more effective therapies.

CONCLUSIONS

High signals in the affected ear indicate a poor hearing prognosis in patients with sudden SNHL. 3D-FLAIR findings may be one of the prognostic factors in sudden SNHL. We believe that this method contributes to the definition of a prognosis for patients with sudden SNHL.

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ORIGINAL ARTICLE

Communication between cochlear perilymph and cerebrospinal fluid through the cochlear modiolus visualized after intratympanic administration of Gd-DTPA

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Abstract
Purpose. Intratympanic injection of gadolinium diethylenetriaminepentaacetic acid (Gd-DTPA) has been reported as a procedure to visualize endolymphatic hydrops of Meniere's disease. We frequently noted that cerebrospinal fluid (CSF) in the internal auditory canal (IAC) was also enhanced after this procedure. The purpose of this study was to evaluate how frequently this occurs and to investigate the specific features of patients who lack this communication.
Materials and methods. A total of 25 patients with clinically suspected endolymphatic hydrops underwent the procedure. After 24 h, three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) and 3D constructive interference in steady state (3D-CISS) were performed. The presence of contrast enhancement in the CSF space of the fundus of the IAC was evaluated.
Results. The contrast ratio between CSF of the IAC fundus and cerebellar white matter on the injected side was 1.49 ± 0.65, and that of the noninjected side was 0.32 ± 0.16 ($P < 0.01$). Enhancement of the CSF space in the IAC fundus was seen in all but two subjects: one had enlarged endolymphatic duct and sac syndrome (EEDS), and the other had cochlear nerve agenesis. In these two patients, the cochlear modiolus seemed to be normal.
Conclusion. Intratympanic Gd-DTPA administration can reveal permeability of the modiolus and might facilitate evaluation of functional abnormalities of the modiolus not detected by conventional imaging tests.

Key words Magnetic resonance imaging · 3D imaging · Anatomy · Modiolus

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Introduction

It has been reported that there is communication between labyrinthine perilymph and the cerebrospinal fluid (CSF) space.[1–4] Physiologically, this communication is important as the origin of perilymph. Perilymph is thought to be derived from both CSF and the vascular supply.[5] Pathologically, this communication is important as a potential route for spreading infection, dissemination, and subarachnoid hemorrhage.[6] In addition, an extremely wide communication might result in a perilymph gusher during a round window operation[7] or cochlear implantation.[8]

Potential communication channels between CSF and perilymph are thought to be the cochlear aqueduct, pores in the cochlear modiolus, and the perineural space in the singular canal. In human adults, the cochlear aqueduct is anatomically totally occluded in 7% of the population and filled with loose connective tissue in 59%; its central lumen is patent in only 34% of the population.[9] A recent histological study revealed that the cochlear modiolus is highly porous.[2] The porous structure in the surface of the modiolus allows communication between perilymph and the perivascular and perineural space in the modiolus. The singular canal contains a nerve branch from the inferior vestibular

nerve, and the perineural space of this canal might communicate with the posterior ampulla and posterior part of the internal auditory canal through the perineural space.

Recently, it was reported that perilymphatic fluid can be enhanced on magnetic resonance imaging (MRI) after intratympanic injection of gadolinium diethylenetriaminepentaacetic acid bis(methylamide) (Gd-DTPA-BMA).[10] Consequently, endolymphatic hydrops can be visualized in patients with Meniere's disease. An enlarged endolymphatic space in patients with Meniere's disease has been successfully recognized as an area with low signal intensity partly surrounded by high-signal perilymphatic fluid on three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) performed after intratympanic injection of Gd-DTPA at 3 tesla.[10] In addition, we noted that the CSF space in the fundus of the internal auditory canal (IAC) was also clearly enhanced in most of the patients, suggesting the possibility of communication between perilymph and the CSF space.

The purpose of this study was to evaluate how frequently communication between cochlear perilymph and CSF is visualized after intratympanic injection of Gd-DTPA and to determine which of the three potential channels is most dominant. Another purpose was to determine the specific features of patients who lack this communication.

Materials and methods

Patients

A total of 25 patients (17 with clinically diagnosed Meniere's disease, 2 with sudden sensorineural hearing loss, 1 with enlarged endolymphatic duct and sac syndrome (EEDS), and 5 with delayed endolymphatic hydrops; age 24–78 years, mean ± SD 48.8 ± 14.8 years; 13 men, 12 women) underwent intratympanic administration of Gd-DTPA-BMA (Omniscan; Daiichi Pharmaceutical, Tokyo, Japan). Two patients underwent intratympanic injection on both sides; thus, 27 ears were further evaluated.

These patients were scheduled for intratympanic injection therapy with gentamicin (for the patients with severe vertigo) or a steroid (for the sudden sensorineural hearing-loss patients). Intratympanic injection of Gd-DTPA was performed to evaluate the status of the endolymphatic space and to simulate drug distribution. Written informed consent was obtained from all patients, and the study was approved by the medical ethics committee of our university hospital.

Intratympanic gadolinium injection

The detailed methods for intratympanic gadolinium injection have been reported previously.[10] In that study, a delay of 24 h between the intratympanic gadolinium injection and MRI was found to be optimal to allow the gadolinium to distribute widely in the perilymphatic space of the labyrinth.

Gd-DTPA-BMA was diluted eightfold with saline (v/v 1:7). The diluted Gd-DTPA-BMA was injected intratympanically through the tympanic membrane using a 23-gauge needle and a 1-ml syringe after the patient was placed in the supine position with his or her head turned approximately 30° away from the sagittal line toward the healthy ear.

MR imaging

All scans were performed on a 3-T MRI scanner (MAGNETOM Trio; Siemens Medical Solutions, Erlangen, Germany) using a receive-only 12-channel phased-array coil. T1-weighted 3D fast low-angle shot (3D-FLASH) and 3D-FLAIR images were acquired 24 h after intratympanic injection of diluted Gd-DTPA-BMA.

In addition, T2-weighted 3D constructive interference in the steady state (3D-CISS) imaging was performed to obtain reference images of the labyrinthine fluid-space anatomy.

The parameters for T1-weighted 3D-FLASH were as follows: repetition time (TR) 4.3 ms, echo time (TE) 1.97 ms, flip angle 10° with radiofrequency (RF) spoiling, matrix size 256 × 256, 96 axial 0.8 mm thick slices with a 16-cm square field of view (FOV). The number of excitations was 2. The total scan time was 2 min 51 s.

The parameters for 3D-CISS were as follows: TR 11.42 ms, TE 5.71 ms, flip angle 50°, matrix size 320 × 320, 48 axial 0.8 mm thick slices with a 16-cm square FOV. The number of excitations was 1, and the scan time was 3 min 42 s.

The parameters for 3D-FLAIR were as follows: TR 9000 ms, effective TE 458 ms, inversion time 2500 ms, variable flip-angle echo train with an average flip angle of 120°, echo-train length 119, matrix size 214 × 256, 48 axial 0.8 mm thick slices with a 15 × 18 cm FOV, acceleration factor of 2 using the GRAPPA parallel imaging technique.[11] The voxel size was 0.7 × 0.7 × 0.8 mm. The number of excitations was 2, and the total scan time was 5 min 26 s. Nonselective inversion pulses and slab-selective excitation pulses were used. The features of this variable flip-angle sequence have been reported elsewhere.[12–14] This sequence allows the use of very long echo-train lengths, in the range of 150–220, without

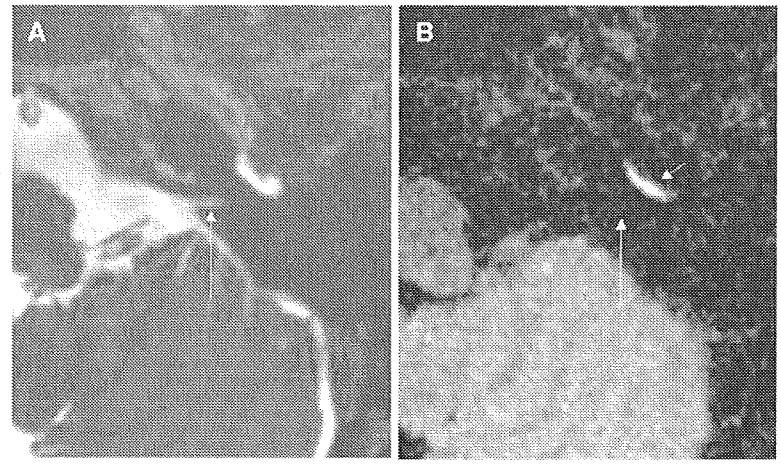

Fig. 1. A 66-year-old woman had Meniere's disease. **a** The cochlear aqueduct is apparent on a three-dimensional constructive interference in steady state (3D-CISS) image (*arrow*). **b** No enhancement of the cochlear aqueduct is seen on a three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) image (*long arrow*). Note that the basal turn of the cochlea is strongly enhanced (*short arrow*)

severe blurring and while maintaining contrast similar to that of 3D-FLAIR obtained with a conventional turbo spin echo sequence, even with a long effective echo time.

Image evaluation

Qualitative evaluation

Two radiologists reviewed the images independently. If a discrepancy existed between the two, consensus was reached through discussion. Enhancement in the fundus of the IAC was evaluated on a negative or positive basis. Enhancement in the cochlear aqueduct, modiolus, and singular canal was also evaluated by referring to the anatomical position of these structures on 3D-CISS.

Contrast enhancement of CSF space in the fundus of the IAC was considered positive if both of the following conditions were fulfilled: (1) No mass other than the cranial nerves existed in the CSF space of the IAC fundus on 3D-CISS. (2) The intensity of the CSF space in the fundus of the IAC was the same or higher than that of the cranial nerves on 3D-FLAIR images.

Contrast enhancement of the cochlear aqueduct, modiolus, and singular canal was considered positive if the intensity of the cochlear aqueduct, modiolus, and singular canal was the same or higher than that of the cranial nerves on 3D-FLAIR images. The positions of the cochlear aqueduct, modiolus, and singular canal were defined by referring to 3D-CISS images.

Quantitative evaluation

The contrast ratio (CR) between the CSF space of the IAC fundus and cerebellar white matter was measured by drawing a region of interest (ROI) on 3D-FLAIR and referring to 3D-CISS images to delineate precisely the CSF space in the IAC. The CR value was defined as the signal of the CSF space in the fundus of the ipsilateral IAC divided by that of the cerebellar white matter on the same side. CR values of the injected side and noninjected side were compared using Student's *t*-test in the 23 patients who had received a unilateral injection.

Results

No side effects related to the intratympanic injection were seen. On T1-weighted 3D-FLASH, contrast enhancement in the labyrinth was quite faint in all patients; therefore, 3D-FLASH images were not used for further evaluation. No enhancement was seen in the cochlear aqueduct (Fig. 1) or the singular canal (Fig. 2) in any of the subjects, even on 3D-FLAIR images. Evaluation of the enhancement in the modiolus was difficult in all subjects owing to the strong enhancement in the surrounding fluid space.

Enhancement of the CSF space in the fundus of the IAC was seen in all but two subjects: One had EEDS, and the other had cochlear nerve agenesis (Figs. 3–5). In these two patients, the cochlear modiolus was slightly small, although its shape was normally developed.

The mean CR value of the injected side was 1.49 ± 0.65, and that of the noninjected side was 0.32 ± 0.16 ($P < 0.01$).

Discussion

In previous MRI studies,[15–17] the size of the cochlear modiolus was measured and was reported to be smaller in patients with EEDS[17] and in those with sudden sensorineural hearing loss.[15]

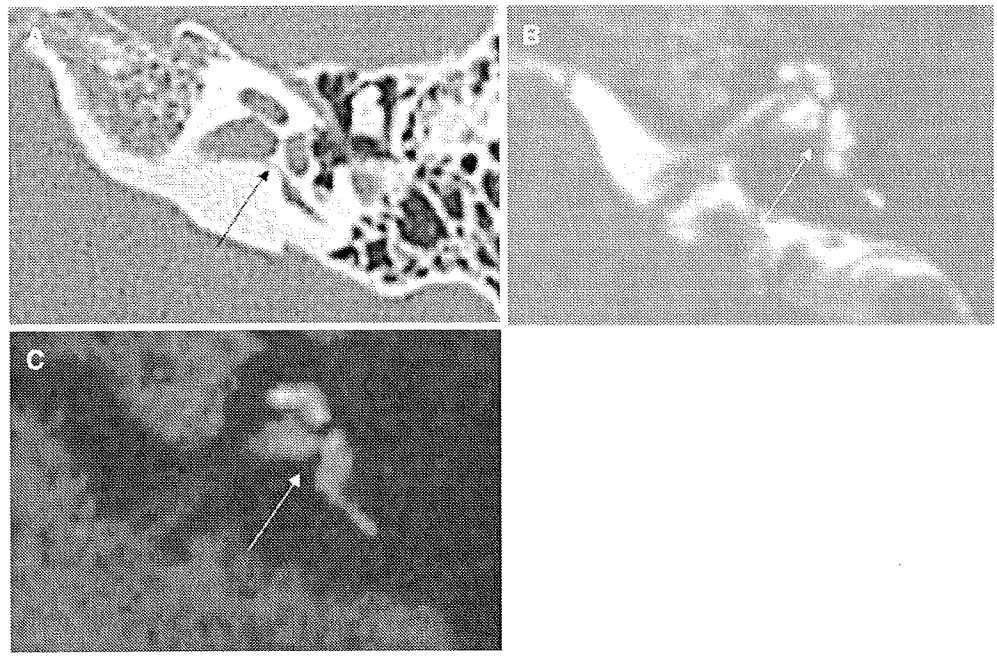

Fig. 2. A 43-year-old woman had Meniere's disease. The singular canal is visualized on computed tomography (CT) (**A**, *arrow*) and 3D-CISS (**B**, *arrow*). **C** No enhancement is seen on 3D-FLAIR (*arrow*), whereas the vestibule is enhanced

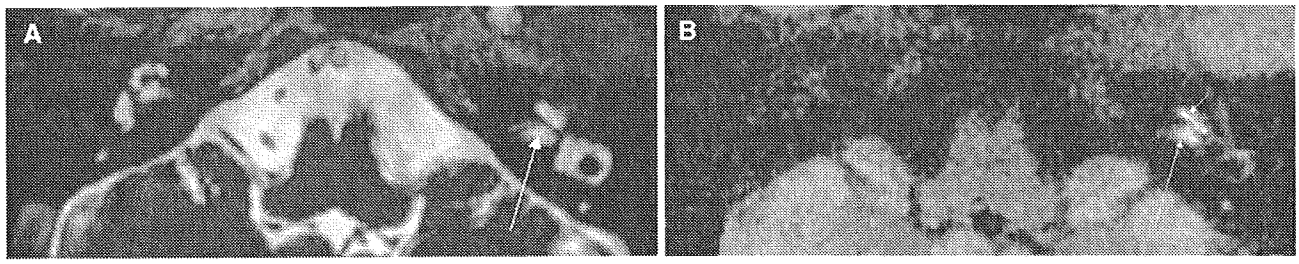

Fig. 3. A 65-year-old woman had Meniere's disease. **A** The cerebrospinal fluid (CSF) space in the fundus of the internal auditory canal (IAC) is apparent on 3D-CISS (*arrow*). **B** On 3D-FLAIR, prominent enhancement of both the CSF space (*arrow*) and the cochlear space (*short arrow*) can be seen

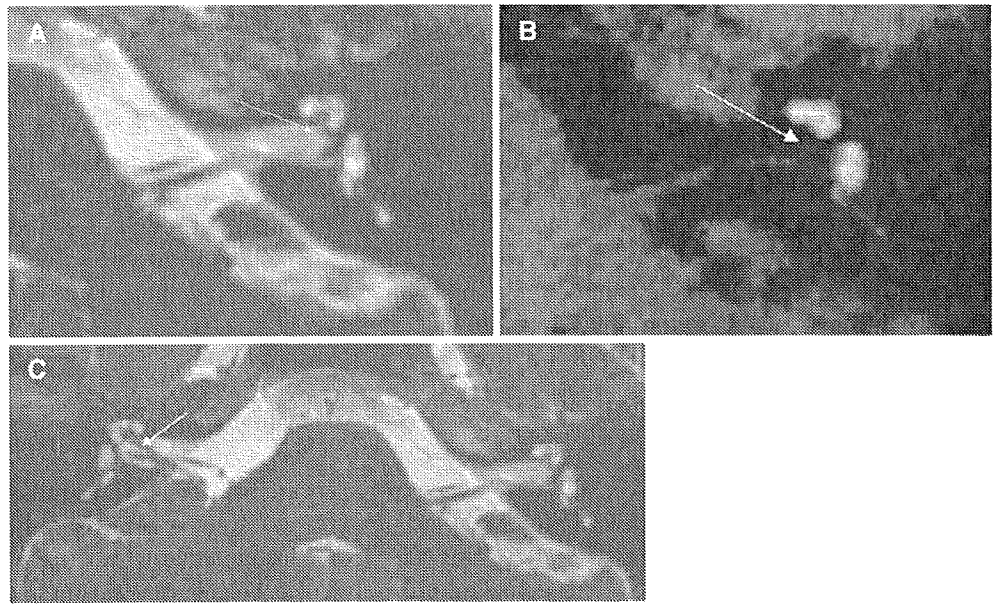

Fig. 4. A 24-year-old man with left-side congenital deafness had been complaining of vertigo and tinnitus for 1 year. Delayed endolymphatic hydrops was suspected. **A** On 3D-CISS, agenesis of the left cochlear nerve is apparent (*arrow*). **B** No enhancement of CSF in the IAC fundus is seen on 3D-FLAIR (*arrow*). **C** Note that the cochlear nerve on the right side is seen to be normally developed on 3D-CISS (*arrow*)

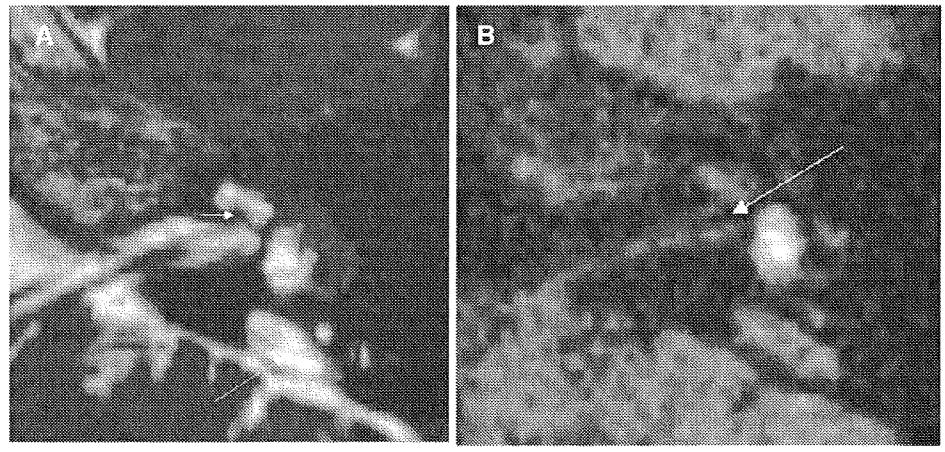

Fig. 5. A 27-year-old man had enlarged endolymphatic duct and sac syndrome (EEDS) and vertigo. **A** On 3D-CISS, an enlarged endolymphatic sac (*long arrow*) and slightly small but normally shaped modiolus (*short arrow*) can be seen. **B** On 3D-FLAIR after intratympanic injection of Gd-DTPA, no enhancement can be seen in the CSF of the IAC fundus (*arrow*)

The modiolus seemed to be slightly small in our patient who had agenesis of the cochlear nerve. The lack of a Rosenthal canal due to cochlear nerve agenesis might be why Gd-DTPA did not penetrate the modiolus, although the Rosenthal canal cannot be visualized with current clinical CT or MRI scanners, even in normal subjects.

In the patient with EEDS, the shape of the cochlear modiolus did not seem to be hypoplastic, although its size is slightly small. Most EEDS patients have a morphologically hypoplastic modiolus.[17,18] In this patient, the shape of the modiolus seemed to be normal; however, the lack of Gd penetration might indicate a microscopic abnormality of the modiolus.

To our knowledge, this is the first report to evaluate permeability of the cochlear modiolus by means of an imaging examination. We showed that communication between perilymph and CSF seems to occur mostly through the modiolus, not through the cochlear aqueduct or singular canal.

Enhancement of the cochlear modiolus was not visualized, which might be attributed to the fact that the strong enhancement of surrounding fluid space made recognition of faint enhancement in the modiolus difficult. The narrow part of the cochlear aqueduct and singular canal might be intrinsically too thin to be visualized on high-spatial-resolution T2-weighted images by clinical MRI. In this study, enhancement was not visualized on 3D-FLAIR images even in the larger part seen on T2-weighted images. To visualize very faint enhancement in the narrow part of the canal, 0.8 mm thick 3D-FLAIR might be too thick. However, such small channels could not be the significant or major communication route.

The patency and function of the cochlear aqueduct have been controversial.[9,19] The central lumen of the cochlear aqueduct is patent throughout in only 34% of adult subjects.[9] The mean diameter of the narrowest portion of the duct was 138 ± 58 μm. Such a narrow channel cannot support fluid flows large enough to explain stapedectomy gushers.[9] However, it has been reported that in newborn infants the cochlear aqueduct is short and patent.[19] A wide, patent cochlear aqueduct might cause endolymphatic hydrops in case of intracranial hypotension. It would be interesting to investigate whether the cochlear aqueduct is enhanced following intratympanic gadolinium injection in the case of a wide, patent cochlear aqueduct.

The clinical relevance of cochlear permeability assessment may be substantial for the following applications.

- Prediction of drug distribution after intrathecal or intratympanic administration
- Prediction of perilymph gusher before stapes surgery
- Evaluation of cochlear modiolar abnormality before cochlear implantation

Currently, we do not recommend intratympanic gadolinium administration for such candidates. Further study is necessary to establish the clinical indications for this examination.

The present study has some limitations. The patients included in the study had symptoms such as hearing loss or vertigo, and no healthy subjects were included. The lack of normal permeability data for the cochlear modiolus is one of the limitations of this study. Although no side effects were observed, intratympanic injection is an off-label use of gadolinium. It is difficult to apply this procedure to normal ears. Animal experiments are possible, although simulating the human normal modiolus might not be possible.

In the previous study using intravenously injected Gd-DTPA, prompt enhancement of the IAC fundus was observed in patients with meningitis without enhancement of the cochlea.[20] This enhancement of the IAC fundus was thought to come from increased permeability of the blood–nerve barrier, not from gadolinium in

perilymph. Further study is necessary to determine whether not only the perineural channel but also the intraneural channel contributes to modiolar permeability after intratympanic injection of Gd-DTPA.

Conclusion

The cochlear modiolus seems to be the main route of communication between perilymph in the labyrinth and CSF in the IAC. Intratympanic Gd-DTPA administration can reveal the permeability of the cochlear modiolus and might be useful for evaluating functional abnormalities of the modiolus not detected by conventional imaging tests.

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突発性難聴に対する局所療法

Topical therapy for the treatment of sudden sensorineural hearing loss

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永井書店

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Topical therapy for the treatment of sudden sensorineural hearing loss

診断の指針 / 治療の指針

中島 務
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1. 突発性難聴とは

突発性難聴の診断基準は，1973年厚生省特定疾患突発性難聴調査研究班により作成され35年経過しているが，突然の高度な感音難聴で原因不明であることが，その診断基準の中心となっている．この診断基準を用いて，今までに4回の全国疫学調査が行われた．突発性難聴は，2001年の全国調査で，年間発症数が3万5千人と推定され，日常診療で少なくない疾患である．

2. 問　　診

問診で，突然聞こえが悪くなった状況を聞く．何月何日に聞こえが悪いことに気づいたと日にちを特定できるのが突発性難聴である．難聴を自覚した日を発症第1日目とするが，時に発症第2日目や3日目の聴力が，1日目より悪くなることがある．発症から1週間くらいまで聴力が低下するものまで，一応，突発性難聴に含めているが，1ヵ月かけて聴力が落ちていったものは，突発性難聴には含めない．

小児例では，難聴が起こっても，それを訴えない例がある．また，成人例でも時に発症に気づかない例もある．突発性難聴は，ほとんどの例で1側性であり，会話は，可能であるからである．耳鼻科の外来に，「電話の受話器をとったら電話が故障していると思った．反対側の耳できいたら聞こえたので，はじめて耳が悪くなっているのに気づいた」といって来院する例がある．このような症例では，電話がなければ発症に気づかなかったので，最後に電話で話したのはいつかなど詳しく問診をとって発症日を特定する．成人例で突発性難聴発症時に異常に気づかない例は，きわめて少ないが，発症を訴えない例が存在することを認識しておく必要がある．

3. 随伴症状

突発性難聴では，9割の症例が耳鳴りを訴える．また約3割の症例でめまいが併発する．この他，耳がふさがったような耳閉感を訴える例が半数程度ある．難聴は，ほとんどの例で内耳性であり，内耳性難聴の特徴である補充現象(リクルートメント現象)を訴えることが多い．補充現象とは，大きな音を内耳でしぼることができないために，小さな音は聞こえないが，大きな音は，不快に響いてしまう現象である．そのため，患耳にわざわざ耳栓をしている例まである．難聴は多くの例で1側性であり，静かなところでの1対1の会話は，とくに問題はないが，ざわざわしたところでの会話が，なかなかできない．これは，ざわざわしたところで聞きたい音のみ聞く能力(カクテルパーティー効果)に，両耳を要するからである．

4. 鑑別診断

原因不明のものを，突発性難聴としているが，原因が明らかな突然の感音難聴に，ムンプス難聴，外リンパ瘻，聴神経腫瘍や頭部外傷後の急性感音難聴などがあげられる．また，最近画像診断の進歩により前下小脳動脈梗塞や内耳出血と診断されるケースが増加してきている．前下小脳動脈梗塞では，時に症状が難聴，耳鳴，めまいなど，一見突発性難聴と同様で，その他の神経症状がない場合があり，注意を要する．MRIで内耳出血が認められた場合，これを突発性難聴として含めるか，内耳出血として分類していくかは，今後の課題である．現在の診断技術では，前下小脳動脈の枝である内耳動脈に梗塞が起こっても，これを診断することができない．

突発性難聴は，原因不明という項目を含んでいるので，診断技術の進歩により，突発性難聴という診断名が減少していくことが期待されている．しかしながら，現段階では，突然に起きる高度の感音難聴のほとんどが，原因不明である．

5. 一般的な治療

突発性難聴では，発症後，聴力は，ほぼ1ヵ月で固

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