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MAIN ARTICLE

Usefulness of three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging to detect inner-ear abnormalities in patients with sudden sensorineural hearing loss

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Abstract

Objective: Three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging has been used to detect alterations in the composition of inner-ear fluid. This study investigated the association between hearing level and the signal intensity of pre- and post-contrast three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging in patients with sudden-onset sensorineural hearing loss.

Method: Three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging was performed in 18 patients with sudden-onset sensorineural hearing loss: 12 patients with mild-to-moderate sensorineural hearing loss (baseline hearing levels of 60 dB or less) and 6 patients with severe-to-profound sensorineural hearing loss (baseline hearing levels of more than 60 dB).

Results: High-intensity signals in the inner ear were observed in two of the six patients (33 per cent) with severe-to-profound sensorineural hearing loss, but not in those with mild-to-moderate sensorineural hearing loss (mid-*p* test, $p = 0.049$). These signals were observed on magnetic resonance imaging scans 6 or 18 days after sensorineural hearing loss onset.

Conclusion: The results indicate that three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging is not a useful tool for detecting inner-ear abnormalities in patients with mild sensorineural hearing loss.

Key words: Labyrinthine Fluids; Hearing Loss, Sudden; Magnetic Resonance Imaging; Signal Detection Analysis

Introduction

Recently, three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging (MRI) has been used to detect alterations in the composition of inner-ear fluid that are difficult to detect using T1- or T2-weighted MRI.[1–6] Yoshida *et al*. have reported that 3D-FLAIR MRI showed high-intensity signals in the affected ears in 31 of 48 patients (65 per cent) with sudden-onset severe sensorineural hearing loss (SNHL).[2] If high-intensity signals are observed near the round window, such as in the vestibule or cochlear basal turn, transtympanic steroid administration for the treatment of sudden-onset SNHL seems justified.[5] However, there are only a few studies available to confirm the potential value of 3D-FLAIR MRI in such patients.

We know that high-intensity signals in the affected ears have not been shown in patients with sudden-onset mild-to-moderate SNHL (personal communication). In our practice we have also observed that 3D-FLAIR MRI does not show high-intensity signals in patients with sudden-onset mild-to-moderate SNHL. However, so far, no study evaluating these patients has been published. This study aimed to investigate the association between hearing levels and the signal intensity of pre- and post-contrast 3D-FLAIR MRI in patients with SNHL, and to assess the clinical relevance of the findings.

Materials and methods

Patients

We evaluated 18 patients who presented at the Aichi Medical University Hospital or affiliated hospitals with complaints of unilateral sudden-onset SNHL. Patients who could describe the day of onset of

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SNHL but did not know its cause were included in the study. Before the onset of SNHL, no hearing loss had been noted. We excluded patients with acute low-tone SNHL, fluctuating hearing loss or progressive hearing loss.[1,7] The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethical committee.

Audiological assessment

Hearing levels were evaluated using an audiometer (models AA-71, AA-73 or AA-75; Rion, Tokyo, Japan) in a sound-insulated chamber. 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 average hearing level was calculated as the mean of the hearing levels measured at 250, 500, 1000, 2000 and 4000 Hz.

Patients were graded according to hearing level: grade 1, hearing level of 40 dB or less; grade 2, hearing level of 41–60 dB; grade 3, hearing level of 61–90 dB; and grade 4, hearing level of 91 dB or more.[8] Patients were then further classified according to two categories of SNHL: mild-to-moderate (grades 1 and 2) and severe-to-profound (grades 3 and 4).

Magnetic resonance imaging

All scans were performed using a 3-T MRI scanner (Trio; Siemens, Erlangen, Germany) using a receive-only, eight-channel, phased-array coil. Three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) MRI was performed before and after the intravenous administration of a single dose of a gadolinium-based contrast agent (Omniscan, 0.1 mmol/kg; Daiichi Sankyo Pharmaceutical, Tokyo, Japan). Heavily T2-weighted three-dimensional and constructive interference in steady-state sequences were performed before the contrast agent was administered, in order to delineate the anatomy of the cerebrospinal fluid space. All patients were also examined using T1- and T2-weighted MRI. These methods have been described in detail previously.[1–3]

The scan parameters for 3D-FLAIR were as follows: repetition time of 9000 ms; effective echo time of 638 ms; variable flip angle echo train with an average flip angle of 151° for turbo spin echo refocusing echo train; echo train length of 171; matrix size of 384×384; 48 axial 0.8 mm thick slices to cover the labyrinth, with a 25.6 cm^2 field of view; and acceleration factor of 2 using the parallel imaging technique (generalised auto-calibrating partially parallel acquisitions). The voxel size was $0.7\ mm \times 0.7\ mm \times 0.8\ mm$. The readout bandwidth was 592 Hz/pixel, and the echo spacing was 3.64 ms. Non-selective inversion pulse and slab-selective excitation pulse were used.

The MRI findings for the inner ear were evaluated by two independent investigators who were blinded to patients' characteristics. The signal was considered as positive when the investigators agreed that the signal intensity of the inner ear was equal to or higher than that of the cerebellum.

Statistics

The mid-*p* test (e.g. Agresti[9] and Karim *et al.*[10]) was used to compare the occurrence of high-intensity signals between the mild-to-moderate SNHL and severe-to-profound SNHL groups. The results were considered statistically significant at a p value of less than 0.05. All statistical analyses were performed with SAS 9.3 software (SAS Institute, Cary, North Carolina, USA).

Results

Patient data

The clinical findings (e.g. patient age, sex, the side affected, average baseline hearing level, severity of hearing loss, and the presence or absence of vertigo) of 18 patients with sudden-onset SNHL are presented in Tables I and II.

In the group with mild-to-moderate SNHL (7 men and 5 women; mean age, 54 years), 7 patients were

TABLE I
CHARACTERISTICS OF SUDDEN SNHL PATIENTS WITH MILD-TO-MODERATE IMPAIRMENT

Pt no.	Age (y), sex	Ear (side affected)	Initial hearing level (affected/unaffected sides; *n*)	Grade	Vertigo?	Clinical features
1	39, F	Right	30/4	1	No	Gall stone
2	55, M	Left	54/23	2	No	Gout, hypertension
3	63, F	Right	43/14	2	No	–
4	56, M	Left	34/18	1	No	Gall stone
5	37, M	Right	35/18	1	No	–
6	65, F	Left	30/23	1	No	–
7	41, M	Right	43/13	2	No	–
8	43, F	Left	23/15	1	Yes	High-frequency hearing loss, breast carcinoma
9	69, F	Left	60/20	2	No	–
10	35, M	Left	37/11	1	No	–
11	81, M	Right	46/25	2	No	Colon carcinoma
12	60, M	Right	39/19	1	No	–

SNHL = sensorineural hearing loss; pt no. = patient number; y = years; F = female; M = male

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TABLE II
CHARACTERISTICS OF SUDDEN SNHL PATIENTS WITH SEVERE-TO-PROFOUND IMPAIRMENT

Pt no.	Age (y), sex	Ear (side affected)	Initial hearing level (affected/unaffected sides; *n*)	Grade	Vertigo?	Clinical features
13	59, F	Left	111/13	4	Yes	–
14	57, M	Right	97/17	4	No	Mediastinal tumour
15	63, M	Right	63/25	3	No	Hypertension
16	63, M	Right	70/33	3	No	Renal failure
17	58, M	Left	111/30	4	Yes	–
18	68, M	Left	69/22	3	Yes	Hypertension

SNHL = sensorineural hearing loss; pt no. = patient number; y = years; F = female; M = male

classified as having grade 1 SNHL and 5 patients as having grade 2 SNHL (Table I). In the group with severe-to-profound SNHL (5 men and 1 woman; mean age, 60 years), 3 patients were classified as having grade 3 SNHL and 3 patients as having grade 4 SNHL (Table II). Four patients (patients 8, 13, 17 and 18) experienced sudden-onset SNHL with vertigo. Nine patients had a history of hypertension, renal failure and other disorders.

Magnetic resonance imaging findings

High-intensity signals were not detected in the inner ear on pre- and post-contrast three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) MRI in any of the patients with mild-to-moderate SNHL (Table III, Figure 1). In contrast, two of the six patients (33 per cent) with severe-to-profound SNHL showed high-intensity signals in the affected inner ear on pre-contrast 3D-FLAIR MRI (Table IV, Figures 2 and 3). The occurrence of high-intensity signals was significantly lower in the mild-to-moderate SNHL group compared with the severe-to-profound SNHL group ($p = 0.049$, mid-p test). Of the two patients with high-intensity signals in the inner ear, one showed high-intensity signals both in the cochlea and vestibule (patient 17, Figure 2a), and the other only in the vestibule (patient 18, Figure 3). Furthermore, on post-contrast 3D-FLAIR MRI, patient 17 showed gadolinium enhancement in the affected inner ear (Figure 2b), but his hearing level showed remarkable improvement.

TABLE III
3D-FLAIR MRI INNER-EAR FINDINGS FOR SUDDEN SNHL PATIENTS WITH MILD-TO-MODERATE IMPAIRMENT

Pt no.	High-intensity signals on 3D-FLAIR MRI		Interval from onset to MRI (days)
	Pre-contrast	Post-contrast	
1	No findings	No enhancement	15
2	No findings	No enhancement	11
3	No findings	Not performed	25
4	No findings	Not performed	36
5	No findings	No enhancement	5
6	No findings	No enhancement	5
7	No findings	No enhancement	2
8	No findings	Not performed	32
9	No findings	No enhancement	14
10	No findings	Not performed	26
11	No findings	Not performed	28
12	No findings	Not performed	29

3D-FLAIR = three-dimensional fluid-attenuated inversion recovery; MRI = magnetic resonance imaging; SNHL = sensorineural hearing loss; pt no. = patient number

- **This study investigated sudden-onset sensorineural hearing loss (SNHL) using three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging (MRI)**
- **It focused on the association between hearing level and the signal intensity of pre- and post-contrast 3D-FLAIR MRI**
- **High-intensity signals in the inner ear were shown only in severe-to-profound SNHL patients**
- **Hence, 3D-FLAIR MRI is not a useful tool for detecting inner-ear abnormalities in mild SNHL patients**

The 3D-FLAIR images can be used to detect subtle changes, even if no hearing loss is shown by pure tone audiometry.[1] In our study, 3D-FLAIR MRI showed negative findings for all contralateral ears, even in patients with high-intensity signals in the affected ear. High-intensity signal areas observed on

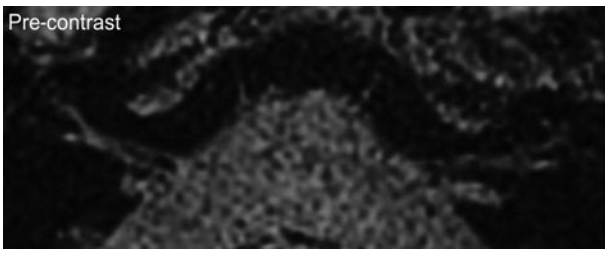

FIG. 1

Patient 2, who had sudden-onset moderate sensorineural hearing loss in the left ear (Table I). No signals were shown either in the cochlea, vestibule or semicircular canals on axial, pre-contrast, three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging (MRI). Contrast-enhanced MRI showed no increase in signal intensity in the inner-ear area.

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TABLE IV
3D-FLAIR MRI INNER-EAR FINDINGS FOR SUDDEN SNHL PATIENTS WITH SEVERE-TO-PROFOUND IMPAIRMENT

Pt no.	High-intensity signals on 3D-FLAIR MRI		Interval from onset to MRI (days)
	Pre-contrast	Post-contrast	
13	No findings	No enhancement	5
14	No findings	No enhancement	8
15	No findings	No enhancement	9
16	No findings	Not performed	9
17	Affected cochlea & vestibule	Enhancement (+)	6
18	Affected vestibule	No enhancement	18

3D-FLAIR = three-dimensional fluid-attenuated inversion recovery; MRI = magnetic resonance imaging; SNHL = sensorineural hearing loss; pt no. = patient number

3D-FLAIR MRI were not detected by T1- or T2-weighted MRI in any of those patients.

The interval between the onset of SNHL and MRI testing ranged from 2 to 36 days (average, 19 days) in the mild-to-moderate group, and from 5 to 18 days (average, 9.2 days) in the severe-to-profound group (Tables III and IV). In the two patients with high-intensity signals, these signals were observed in MRI scans performed 6 or 18 days (patients 17 and 18, respectively) after SNHL onset.

Discussion

In the present study, three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) MRI revealed no high-intensity signals in the cochlea in any of the patients with sudden-onset mild-to-moderate SNHL (grades 1 and 2), but such signals were revealed in two patients with sudden-onset severe-to-profound SNHL (grades 3 and 4). Our results indicate that 3D-FLAIR MRI is not a useful tool for detecting alterations in the composition of the labyrinthine lymph fluid in patients with sudden-onset mild SNHL.

The reasons why patients with mild-to-moderate SNHL did not show high-intensity signals in the inner ear remain unclear. Several authors have speculated that high-intensity signals on 3D-FLAIR MRI may reflect an increased concentration of protein that originates from disrupted cells, or haemorrhages in the inner ear.[1–3] One possible explanation is that such damage to the inner ear was less severe in patients with SNHL grades 1 and 2 compared with those with SNHL grades 3 and 4. Berrettini *et al.* reported that the baseline hearing level was significantly worse in the group with positive 3D-FLAIR findings compared with those with negative findings.[5] The presence of a high-intensity signal is also associated with poorer hearing recovery[2–4] and vestibular abnormalities.[4,6]

Our study provides important data on the usefulness of 3D-FLAIR MRI for diagnosing inner-ear abnormalities in SNHL. However, the study has some limitations. We did not include an age-matched control group,[5] although all contralateral ears showed negative 3D-FLAIR findings. Moreover, our study comprised a relatively small number of patients. The results are preliminary; further studies are needed to determine the optimal interval period from the onset of SNHL to the performance of MRI.

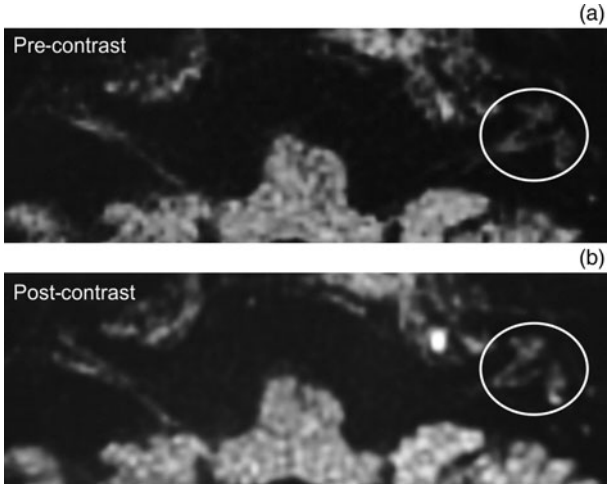

FIG. 2

Patient 17, who had sudden-onset profound sensorineural hearing loss with vertigo in the left ear (Table II). High-intensity signals (encircled) were shown in the left cochlea and vestibule on axial, pre-contrast, three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging (MRI) (a). Contrast-enhanced MRI showed an increase in signal intensity (encircled) in the areas that had high-intensity signal on pre-contrast 3D-FLAIR MRI (b).

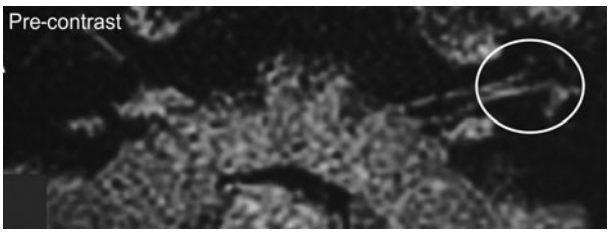

FIG. 3

Patient 18, who had sudden-onset severe sensorineural hearing loss with vertigo in the left ear (Table II). High-intensity signals (encircled) were shown in the left vestibule, but no signals were shown in the left cochlea on axial, pre-contrast, three-dimensional fluid-attenuated inversion recovery (3D-FLAIR) magnetic resonance imaging (MRI). Contrast-enhanced MRI showed no increase in signal intensity in the areas that had high-intensity signal on pre-contrast 3D-FLAIR MRI.

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In conclusion, 3D-FLAIR MRI may not be a useful tool for detecting inner-ear abnormalities in patients with sudden-onset mild SNHL. To our knowledge, this is the first study to have reported that 3D-FLAIR MRI does not detect inner-ear abnormalities in this patient group.

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