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MAIN ARTICLE

Diagnostic value of three-dimensional magnetic resonance imaging of inner ear after intratympanic gadolinium injection, and clinical application of magnetic resonance imaging scoring system in patients with delayed endolymphatic hydrops

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Abstract

Objective: Three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging of the inner ear after intratympanic injection of gadolinium, together with magnetic resonance imaging scoring of the perilymphatic space, were used to investigate the positive identification rate of hydrops and determine the technique's diagnostic value for delayed endolymphatic hydrops.

Methods: Twenty-five patients with delayed endolymphatic hydrops underwent pure tone audiometry, bithermal caloric testing, vestibular-evoked myogenic potential testing and three-dimensional magnetic resonance imaging of the inner ear after bilateral intratympanic injection of gadolinium. The perilymphatic space of the scanned images was analysed to investigate the positive identification rate of endolymphatic hydrops.

Results: According to the magnetic resonance imaging scoring of the perilymphatic space and the diagnostic standard, 84 per cent of the patients examined had endolymphatic hydrops. In comparison, the positive identification rates for vestibular-evoked myogenic potential and bithermal caloric testing were 52 per cent and 72 per cent respectively.

Conclusion: Three-dimensional magnetic resonance imaging after intratympanic injection of gadolinium is valuable in the diagnosis of delayed endolymphatic hydrops and its classification. The perilymphatic space scoring system improved the diagnostic accuracy of magnetic resonance imaging.

Key words: Endolymphatic Hydrops; MRI Scans; Gadolinium; Ear, Inner; Pathology; Diagnosis

Introduction

Delayed endolymphatic hydrops is a condition similar to Ménière's disease. However, delayed endolymphatic hydrops has a well-defined aetiology. Nadol *et al*. initially reported this disease in 1975,[1] and Schuknecht named and comprehensively described its classification in 1978.[2] Delayed endolymphatic hydrops manifests as recurrent vertigo following severe unilateral or bilateral hearing loss. It often occurs in patients with previous pathological damage to the ear.

Endolymphatic hydrops is currently diagnosed using data obtained from glycerol testing, electrocochleography, bithermal caloric testing, vestibular-evoked myogenic potential testing and so on. Routine high-resolution magnetic resonance imaging (MRI) hydrography of the inner ear alone cannot identify endolymphatic hydrops in delayed endolymphatic hydrops patients. In 2007, Nakashima and colleagues successfully used three-dimensional (3D) fluid-attenuated inversion recovery ('FLAIR') MRI after transtympanic gadolinium injection to image the perilymphatic space of the inner ear and detect endolymphatic hydrops.[3] In 2012, Fang *et al*. proposed two simple and effective MRI scoring methods for diagnosing endolymphatic hydrops.[4] These techniques provide a reliable standard for imaging-based diagnoses of Ménière's disease and delayed endolymphatic hydrops.

In the current study, we administered an intratympanic injection of gadolinium-diethylenetriamine penta-acetic acid dimeglumine solution to 25 delayed endolymphatic hydrops patients and performed inner-ear 3D fluid-attenuated inversion recovery MRI 24

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hours later. The scanned images of the perilymphatic space were analysed to investigate the positive identification rate of endolymphatic hydrops in delayed endolymphatic hydrops patients. The value of this technique for the clinical classification and diagnosis of delayed endolymphatic hydrops was evaluated.

Materials and methods

Clinical data

The current study comprised 25 patients diagnosed with delayed endolymphatic hydrops at the ENT department of the First Affiliated Hospital of Fujian Medical University from February 2010 to June 2012. The diagnostic criteria of delayed endolymphatic hydrops included: a history of moderately severe or severe sensorineural hearing loss in one ear, Ménière's disease like vestibular symptoms as the subsequent presentation, and endolymphatic hydrops as indicated by electrocochleography or glycerol testing. Imaging examinations (computed tomography or MRI) were used to exclude retrocochlear lesions.

Delayed endolymphatic hydrops was classified as ipsilateral, contralateral or bilateral. The ipsilateral type was characterised by: severe sensorineural hearing loss or deafness of one ear, Ménière's disease like episodes of vertigo occurring several years later (often accompanied by nausea and vomiting), occasionally tinnitus and ear fullness, and positive laboratory test results for endolymphatic hydrops in the affected ear but not in the contralateral ear. The contralateral type was characterised by fluctuating hearing loss in the contralateral ear after severe hearing loss or deafness in the other ear, with or without Ménière's disease like episodes of vertigo, and positive laboratory test results for endolymphatic hydrops in the contralateral ear but not in the ipsilateral ear. Patients with the bilateral type had bilateral hearing loss prior to the occurrence of endolymphatic hydrops.

There were 14 male and 11 female patients in the study, with a mean age of 43.32 ± 15.62 years (range of 13–74 years). In all patients, intratympanic injection of gadolinium-diethylenetriamine penta-acetic acid dimeglumine solution was carried out within one week after the last episode of vertigo. The ear canal and eardrum were intact before the injection. All patients underwent pure tone audiometry, bithermal caloric testing and vestibular-evoked myogenic potential testing. Eight patients underwent electrocochleography.

This study was approved by the internal institutional review board of our hospital. All participating patients or their legal surrogates gave written informed consent to participate in the study. The study followed the ethical guidelines of the Declaration of Helsinki.

Magnetic resonance imaging examination

A gadolinium-diethylenetriamine penta-acetic acid dimeglumine injection solution (Magnevist; Schering, Guangzhou, China) was used as the contrast medium. Gadolinium hydrate diluted eightfold with saline was injected intratympanically through the tympanic membrane (using a 23-gauge needle) in 50 ears of 25 patients. Twenty-four hours later, 3D fluid-attenuated inversion recovery MRI was performed using a 3.0-Tesla unit. Magnetic resonance imaging was conducted using a Verio 3.0-Tesla 16-channel head system (Siemens, Erlangen, Germany). The images obtained included: routine sagittal turbo spin echo T2-weighted images through the internal auditory canal; routine MRI hydrography of the inner ear, which served as a reference for labyrinth anatomy; and isotropic 3D sampling perfection with application-optimised contrast using different flip angle evolutions ('3D-SPACE') fluid-attenuated inversion recovery.

Imaging methods for endolymphatic hydrops evaluation

Routine hydrography images were processed with three-dimensional, multiplanar reconstruction and maximum intensity projection, using the Syngo suite (Siemens, Erlangen, Germany). Using labyrinth hydrography scans as the anatomical reference, gadolinium distribution in the labyrinth was quantitatively scored by two radiologists in an independent, double-blinded manner. The scoring criteria are shown in Table I. A score of 3 in the vestibular aspect reflected a low-signal image of the saccule found medial to the vestibule below the horizontal semicircular canal, accompanied by a normal image of the vestibule above the horizontal

TABLE I
INNER-EAR MRI SCORING CRITERIA*

Appearance	Cochlea			Vestibule	Semicircular canals		
	Base	Middle	Apex		Superior	Horizontal	Posterior
Not visible†	0	0	0	0	0	0	0
Partially visible‡	1	1	1	3	1	1	1
Completely visible**	2	2	2	6	2	2	2

Data represent scores to be given. *For three-dimensional sampling perfection with application-optimised contrast using different flip angle evolutions ('SPACE') fluid-attenuated inversion recovery ('FLAIR') images (time of inversion = 2100 ms). †Absence of high-signal contrast medium. ‡Either: failure to show high-signal image of entire cochlear canal; high-signal image of cochlear canal limited to tympanic or vestibular scale; interrupted high-signal images of semicircular canals; or incomplete high-signal image of vestibule. **All labyrinth structures completely visible. MRI = magnetic resonance imaging

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semicircular canal, together with a dumbbell-shaped utricle.

The presence of endolymphatic hydrops was evaluated on the basis of two convenient and effective perilymphatic space MRI scoring methods. These methods were proposed by Fang *et al.* for endolymphatic hydrops diagnosis.[4] A diagnostic function was developed (based on the scores for the different labyrinth components): 65.026 – (0.418 × cochlear score) – (7.938 × vestibular score) – (3.939 × semicircular canal score). A diagnosis of endolymphatic hydrops was made if the score of the function reached 0.3982299. The other diagnostic method was based on the total MRI scores. Specifically, a diagnosis of endolymphatic hydrops was made when the direct sum of all scores from the different aspects fell below 14.5.

Pure tone audiometry

Audiometry was carried out with an OB922 pure tone audiometer (Madsen, Copenhagen, Denmark), using the 'up and down' method of threshold estimation (i.e. up 5 dB, down 5 dB). Hearing loss was graded based on the mean threshold value of three frequencies (0.5, 1.0 and 2.0 kHz), according to the international grading standard of hearing loss (World Health Organization, International Classification of Impairments, Disabilities and Handicaps, 1980).[5]

Electrocochleography

Electrocochleography was conducted using a VikingQuest evoked potential system (Nicolet, Madison, Wisconsin, USA). The stimulating electrodes were placed outside the tympanum. A summating potential and action potential ratio of more than 0.40 was considered to be abnormal.

Bithermal caloric testing

The patient was placed in a 30-degree, head-up supine position. The ear was examined by infusing 25°C cold air and 46°C hot air using a Varioair caloric stimulator (Atmos, Lenzkirch, Germany). Nystagmus was recorded after the infusion using infra-red video cameras (Ulmer video-nystagmography system; Synapsys, Marseilles, France). A canal paresis value of more than 25 per cent was considered to be abnormal.

Vestibular-evoked myogenic potential testing

The patient was placed in the supine position and asked to raise his or her head during measurement to maintain tonic contraction of the sternocleidomastoid muscle. Vestibular-evoked myogenic potential was recorded under bilateral click stimulation. The stimulating sound was a 0.1 ms click noise, with an intensity of 95 dB nHL, at a rate of 5.1 per second. The bandpass filter frequency ranged from 0.01 to 20.00 kHz, and the stimulating frequency was 100 Hz. The recorded electromyography (EMG) signal was rectified and the difference waveform (reflecting the difference between the EMG recordings of sternocleidomastoid muscle activity with and without click stimulation) was used for analysis. The results were considered abnormal if: the p13–n23 component disappeared, the latency was extended (if the upper limit of p13 latency was ≥17.30 ms and/or the upper limit of n23 latency was ≥24.62 ms), the ratio of bilateral amplitudes was ≥1.61 or the asymmetry amplitude was ≥0.29.[6]

Statistical analysis

Analyses were conducted with McNemar's test, using the Statistical Package for the Social Sciences version 17.0 software (SPSS, Chicago, Illinois, USA). The results of 3D fluid-attenuated inversion recovery MRI after transtympanic gadolinium injection were compared with those of bithermal caloric testing and vestibular-evoked myogenic potential testing. A p value of <0.05 was considered to be statistically significant.

Results

Audiometry, disease classification and electrocochleography results

Of the 25 delayed endolymphatic hydrops patients, 3 had moderately severe sensorineural hearing loss (56–70 dB HL), 5 had severe sensorineural hearing loss (71–90 dB HL) and 17 had extremely severe sensorineural hearing loss (>90 dB HL).

Regarding the delayed endolymphatic hydrops classification, 23 patients had the ipsilateral type and 2 patients had the contralateral type.

Of the eight patients who underwent electrocochleography, two had abnormal findings, five had no action potential or summating potential, and one case was normal. Therefore, electrocochleography only provided meaningful diagnostic evidence in 25 per cent of the patients (2 out of 8).

Magnetic resonance imaging results

The results showed that the contrast medium was distributed widely in the perilymphatic space of the cochlea, vestibule and semicircular canals. This served to enhance the imaging of perilymph, distinguish the boundary between the endolymphatic space and the perilymphatic space, and clearly show the state of the membranous labyrinth. As shown in Figure 1, both the perilymphatic space (a high-signal area) and the endolymphatic space (a low-signal area) could be observed within the cochlea and vestibule. The results of the quantitative MRI scoring method (reflecting the distribution of the gadolinium contrast medium in the labyrinth) and the two diagnostic MRI scoring methods are shown in Table II.

Quantitative scoring (based on the MRI scoring standard of the inner ear (Table I)) and diagnostic scoring calculations were carried out for the MRI images of all patients to determine the presence of endolymphatic hydrops (Table II). This detected 21 patients with the disease, a positive identification rate of 84 per cent. The ears identified with endolymphatic hydrops in

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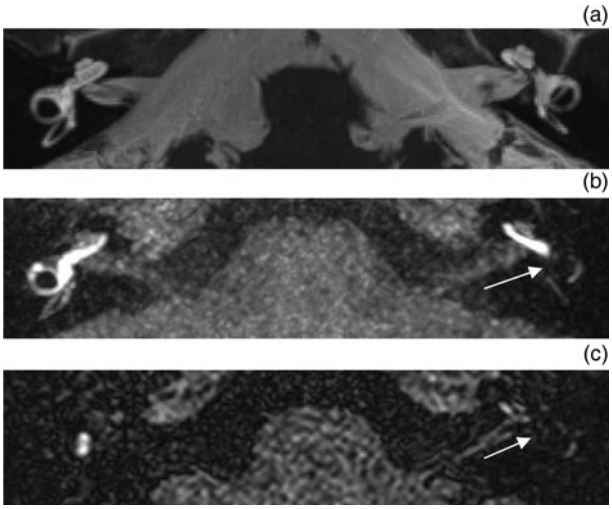

FIG. 1

Axial magnetic resonance imaging (MRI) scans of 31-year-old female with ipsilateral (left-sided) delayed endolymphatic hydrops: (a) routine MRI hydrography image (maximum intensity projection), showing symmetrical signal for bilateral labyrinth structures without abnormality; (b) three-dimensional sampling perfection with application-optimised contrast using different flip angle evolutions ('SPACE') fluid-attenuated inversion recovery ('FLAIR') image (maximum intensity projection reconstruction), showing high-signal image of cochlear canal limited to tympanic scale, interrupted high-signal images of horizontal and posterior semicircular canals, and absence of high-signal contrast medium in vestibule (arrow); and (c) thin-section original image from scan (b) (arrow indicates vestibule with no high-signal contrast medium).

the MRI evaluation were the same ears that had been diagnosed clinically with delayed endolymphatic hydrops.

Only 3 of the 25 patients experienced dizziness after the gadolinium contrast medium was injected. This improved after a brief rest and there were no other symptoms. No eardrum perforation was found one week later, and there were no complications such as middle-ear infection.

Test results comparison

The positive identification rates (the number of patients identified as having the disease out of the number of patients tested) were: 52 per cent (13 out of 25) for vestibular-evoked myogenic potential testing, 72 per cent (18 out of 25) for bithermal caloric testing and 84 per cent (21 out of 25) for 3D fluid-attenuated inversion recovery MRI after transtympanic gadolinium injection (Table III). There was a significant difference between the identification rates for 3D fluid-attenuated inversion recovery MRI and vestibular-evoked myogenic potential testing ($p < 0.05$), while there was no significant difference between the rates for 3D fluid-attenuated inversion recovery MRI and bithermal caloric testing ($p > 0.05$).

Discussion

Delayed endolymphatic hydrops is associated with Ménière's disease like episodes of vertigo that occur

TABLE II
MRI SCORING RESULTS*

Cochlea			Vestibule	Semicircular canals			Diag score – diff	Diag score – sum	Endolymphatic hydrops?
Base	Middle	Apex		Superior	Horizontal	Posterior			
1	1	1	0	1	2	0	51.955	6	Yes
1	1	1	0	0	2	1	51.955	6	Yes
1	1	1	3	1	2	1	24.202	10	Yes
2	2	2	6	2	2	2	−8.744	18	No
2	2	2	6	2	2	2	−8.744	18	No
2	2	2	3	1	2	1	22.948	13	Yes
1	0	0	0	0	1	1	56.73	3	Yes
1	1	1	3	1	2	1	24.202	10	Yes
2	2	2	3	1	1	1	30.826	12	Yes
2	2	2	0	1	1	1	50.701	9	Yes
1	0	0	3	0	1	0	36.855	5	Yes
1	2	2	6	1	1	1	3.491	14	Yes
1	1	1	3	1	2	2	20.263	11	Yes
1	1	1	0	1	1	1	51.955	6	Yes
1	1	1	0	1	1	1	51.955	6	Yes
1	1	1	3	1	2	1	24.202	10	Yes
1	0	0	0	1	0	0	60.669	2	Yes
1	1	1	0	1	2	1	48.016	7	Yes
2	2	2	6	2	2	2	−8.744	18	No
1	1	1	0	1	1	1	51.955	6	Yes
1	1	1	0	1	2	1	48.016	7	Yes
1	1	2	0	1	2	2	43.659	9	Yes
2	2	2	6	2	2	2	−8.744	18	No
2	2	2	3	2	2	2	15.07	15	Yes
1	1	1	0	0	1	1	55.894	5	Yes

Numerical data represent scores given. *Quantitative results of gadolinium contrast medium distribution in the labyrinth and diagnostic scoring results. MRI = magnetic resonance imaging; Diag score – diff = results of diagnostic method based on the scores for different labyrinth components (diagnosis of endolymphatic hydrops was made when the diagnostic function score reached 0.3982299); Diag score – sum = results of diagnostic method based on the direct sum of all scores from different aspects of the labyrinth (diagnosis of endolymphatic hydrops was made when the sum fell below 14.5).

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TABLE III
POSITIVE IDENTIFICATION RATES*

Examinations	Positive cases (*n*)	Negative cases (*n*)	Positive rate (%)	*p*
Gadodiamide-enhanced MRI	21	4	84	
VEMP testing	13	12	52	0.021†
Bithermal caloric testing	18	7	72	0.508‡

*Of various examinations in detecting endolymphatic hydrops. †Gadodiamide-enhanced magnetic resonance imaging (MRI) positive identification rate versus vestibular-evoked myogenic potential testing rate. ‡Gadodiamide-enhanced MRI positive identification rate versus bithermal caloric testing rate. MRI = magnetic resonance imaging; VEMP = vestibular-evoked myogenic potential

after unilateral or bilateral hearing loss. Among the causes of sensorineural hearing loss, unexplained causes and unilateral hearing loss occurring in childhood or young adulthood account for more than 50 per cent of cases. Other causes include viral or bacterial labyrinthitis, noise-induced inner-ear damage, otosclerosis, congenital cytomegalovirus infection, head trauma and mastoid surgery.[7] Hearing loss alone occurs during the early stage of delayed endolymphatic hydrops; vestibular function is often unaffected. As the disease progresses, the following may occur: atrophy or fibrosis of the endolymphatic absorption system, and damage to the endolymphatic sac or the vestibular aqueduct. This leads to progressive endolymphatic hydrops.

The principle of inner-ear 3D-MRI hydrography is as follows. After entering the tympanum, gadolinium contrast medium penetrates the round window membrane and enters the perilymphatic space of the cochlea, vestibule and semicircular canals. This enhances the MRI images of the perilymphatic space within the labyrinth. Therefore, this technique can clearly distinguish the boundary between the endolymphatic space and the perilymphatic space, and make the direct observation of endolymphatic hydrops possible.

In the current study, 21 of 25 patients had inner-ear endolymphatic hydrops signs according to MRI: a positive identification rate of 84 per cent. The ears identified with endolymphatic hydrops in the MRI evaluation were the same ears that had been diagnosed clinically with delayed endolymphatic hydrops, which is consistent with the reports of Fukuoka *et al.*[8] and Fiorino *et al.*[9] These results suggest that the success rate and reliability of this hydrography technique are high. Traditionally, the clinical diagnosis of delayed endolymphatic hydrops is based mainly on patient history, typical symptoms, and the results of hearing and vestibular function tests. These methods lack relatively direct and visual evidence. By contrast, 3D fluid-attenuated inversion recovery MRI using an intratympanic injection of gadolinium can clearly present the state of endolymphatic hydrops and provide relatively objective evidence for the diagnosis of delayed endolymphatic hydrops.

Intratympanic injection of gadolinium contrast medium is a simple procedure with a high success rate. The patient does not feel obvious discomfort after surface anaesthesia of the eardrum; this technique is often readily accepted. There were no complications (such as eardrum perforation or infection) in the current study, which suggests that the risk is within an acceptable range. Of course, additional studies with larger samples should be carried out for further risk evaluation.

At present, clinical diagnostic methods for endolymphatic hydrops include glycerol testing, electrocochleography, bithermal caloric testing and vestibular-evoked myogenic potential testing. The state of endolymphatic hydrops can only be inferred using these methods, via the detection of indirect signs. For example, glycerol testing identifies the presence of endolymphatic hydrops according to hearing threshold fluctuations after dehydration achieved by the oral intake of glycerine. However, false negative results may sometimes occur with this test (e.g. during the relief period, when hearing loss is mild or when there is no fluctuation in severely damaged hearing function).

The assumption underlying electrocochleography used for diagnosing this disease is that endolymphatic hydrops changes the location of the basement membrane to affect the cochlea-related potential amplitude, which is presented as an abnormal summating potential and action potential ratio in the examination. However, many factors influence the electrophysiological activity of the cochlea. In addition, some scholars suggest that the abnormal summating potential and action potential ratio can also be observed in non-Ménière's disease cases, and that the ability of electrocochleography to accurately reflect endolymphatic hydrops is poor.[10] In 1985, Ferraro *et al.* stated that sufficient residual hearing function is a prerequisite for a clear recording of electrocochleogram waveforms.[11] In cases with extremely severe hearing loss, the magnitude of stimulating sound is not sufficient. This results in a nonexistent or weakened composite waveform (reflective of the action potentials evoked by the stimulus), making subsequent analyses impossible.[12] Because of the presence of serious hearing loss, electrocochleography is not appropriate for patients with the ipsilateral type of delayed endolymphatic hydrops. In the current study, the results recorded were meaningless for five of the eight patients who underwent electrocochleography. As the ipsilateral type is the most common type of delayed endolymphatic hydrops and the hearing damage is relatively severe in these cases, electrocochleography is less useful for the diagnosis of ipsilateral delayed endolymphatic hydrops than for Ménière's disease.

Bithermal caloric testing is useful for detecting stable vestibular lesions. However, there are some

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disadvantages of this test.[13] For instance, it mainly reflects semicircular canal function, especially lateral semicircular canal function; it cannot therefore provide a comprehensive evaluation of vestibular function or indicate the state of endolymphatic hydrops. In addition, the test often evokes a vestibulo-autonomic reflex, which makes the patient feel uncomfortable. The bithermal caloric stimulation is not a normal physiological stimulus of the semicircular canal. Hence, this kind of examination should not be considered as a 'gold standard' for diagnosis.

Vestibular-evoked myogenic potential testing is a traditional method for examining the sacculo-neck reflex. Young *et al.* investigated the use of this method in delayed endolymphatic hydrops cases and found three possible abnormalities in vestibular-evoked myogenic potential recordings associated specifically with the evaluation of saccular function.[14] These were: the absence of the vestibular-evoked myogenic potential, low amplitude and the extension of p13 latency.

In the current study, the positive identification rates (of endolymphatic hydrops) for vestibular-evoked myogenic potential testing and bithermal caloric testing were 52 per cent and 72 per cent, respectively. These results are in accordance with other related reports.[15] Bithermal caloric testing results mainly reflect horizontal semicircular canal function, while the results of vestibular-evoked myogenic potential testing mainly reflect saccular function. Both tests provide relatively limited and indirect evidence for a diagnosis of delayed endolymphatic hydrops. However, 3D fluid-attenuated inversion recovery MRI, using an intratympanic injection of gadolinium, provides visible morphological evidence for a diagnosis of this disease and can detect the presence of endolymphatic hydrops with a high sensitivity. Moreover, the new MRI evaluation standard for the inner-ear perilymphatic space can provide a comprehensive evaluation of the endolymphatic hydrops state, with relatively high diagnostic accuracy and specificity.

Egami *et al.* found that vestibular-evoked myogenic potential testing and glycerol testing combined could enable relatively accurate identification of delayed endolymphatic hydrops.[16] However, the technique of 3D fluid-attenuated inversion recovery MRI after transtympanic gadolinium injection can directly show the state of endolymphatic hydrops, and can identify delayed endolymphatic hydrops more accurately and easily than the method described by Egami *et al.*

Accurate identification of the clinical type of delayed endolymphatic hydrops is very important in patients whose quality of life is adversely affected by dizziness (after active medication and psychological treatments). The identification of clinical type is directly related to subsequent decisions regarding surgical treatment. For patients with severe hearing loss due to ipsilateral delayed endolymphatic hydrops, chemical labyrinthectomy or open labyrinthectomy will be helpful. For patients with the contralateral type, endolymphatic sac surgery is a relatively safe option. It can eliminate or control vertigo, and maintain or improve hearing function. Therefore, accurate identification of the delayed endolymphatic hydrops type can lead to treatment that effectively improves the patient's symptoms and preserves residual hearing function.

- **Clinical diagnosis of delayed endolymphatic hydrops is based on history, audiology and vestibular function tests**
- **This study investigated three-dimensional fluid-attenuated inversion recovery magnetic resonance imaging (MRI) after transtympanic gadolinium injection**
- **This can be used to image the perilymphatic space of the inner ear to detect endolymphatic hydrops**
- **The technique is useful for delayed endolymphatic hydrops diagnosis and classification**
- **Scoring of perilymphatic space improves MRI diagnostic accuracy for this disease**

Some aspects of delayed endolymphatic hydrops remain unclear; for instance, the pathogenesis and development of delayed endolymphatic hydrops, and the relationship between endolymphatic hydrops and recurrent symptoms. Three-dimensional fluid-attenuated inversion recovery MRI using an intratympanic injection of gadolinium provides a reliable imaging method for studying the disease. In our study, there were four cases in which MRI did not detect endolymphatic hydrops signs. Further study is required to investigate whether the negative results were related to the testing time point or to pathogenesis.

Conclusion

Overall, 3D fluid-attenuated inversion recovery MRI using an intratympanic injection of gadolinium enabled direct identification of endolymphatic hydrops state. This technique is a valuable and sensitive diagnostic indicator of all delayed endolymphatic hydrops types. The introduction and application of the new MRI scoring standard for the inner-ear perilymphatic space could improve the accuracy of MRI in the diagnosis of delayed endolymphatic hydrops.

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