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Original Article

The Diagnostic Value of 1.5T Versus 3.0T Magnetic Resonance Imaging Intratympanic Gadolinium Inner Ear Enhancement in Patients with Meniere's Disease

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BACKGROUND: A comparative study of 1.5T and 3.0T magnetic resonance imaging inner ear gadolinium enhancement was carried out to further explore the practicality and universality of 1.5T magnetic resonance imaging in the diagnosis of inner ear labyrinthine hydrops positive imaging.

METHODS: This dual case–control study was conducted on 25 patients with Meniere's disease (experimental group), diagnosed by People's Hospital of Ordos Dongsheng District between April 2017 and April 2019 and 51 patients with Meniere's disease (control group), diagnosed by People's Hospital Affiliated to Fujian University of Traditional Chinese Medicine between March 2010 and February 2011 and published on *Chinese Medical Journal* in 2011. Both groups were injected with gadolinium diluent into bilateral tympanic chambers through the tympanic membrane, and 3 dimensional-Fluid Attenuated Inversion Recovery (FLAIR) magnetic resonance imaging scanning of the inner ear was performed 24 hours later. The results of the 2 groups were observed, calculated, and statistically processed.

RESULTS: The positive rate of membranous labyrinthine hydrops was 96% (24/25) in the experimental group and 96.1% (49/51) in the control group. The results are very close.

CONCLUSION: In clinical diagnoses of Meniere's disease, 1.5T magnetic resonance imaging and 3.0T magnetic resonance imaging have the same value and significance.

KEYWORDS: Inner ear, gadolinium enhancement, labyrinthine hydrops, Meniere's disease

INTRODUCTION

At present, many hospitals in many countries and regions have carried out 3.0T magnetic resonance imaging (MRI) gadolinium enhancement of inner ear, but there are only a few reports on 1.5T MRI gadolinium enhancement of inner ear, and there are no relevant reports on the comparative study of 1.5T MRI and 3.0T MRI gadolinium enhancement of inner ear. It has been reported that Meniere's disease, traumatic disease of inner ear, sudden deafness, low-frequency sensorineural deafness, recurrent peripheral vestibular disease, atypical Meniere's disease, semicircular canal dysplasia, semicircular canal fissure syndrome, vestibular aqueduct syndrome, and so on are the diseases with membranous labyrinthine hydrops. However, the most representative disease based on membrane labyrinth hydrops is Meniere's disease, so this study chose Meniere's disease as the research disease. At present, the only imaging method that can see labyrinthine hydrops in the inner ear membrane in vivo is the gadolinium of the inner ear. In some underdeveloped countries and regions, hospitals often only have 1.5T MRI. If 1.5T MRI gadolinium enhancement of the inner ear can be popularized in these countries and regions, it will definitely promote the development of imaging diagnosis of

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Table 1. Diagnostic Basis of 2006 Guiyang Conference

Serial Number	Diagnostic Basis
1	Paroxysmal rotational vertigo twice or more, lasting 20 minutes to several hours each time. It is often accompanied by autonomic nerve dysfunction and balance disorder. Unconscious disorder.
2	Fluctuating hearing loss, mostly low-frequency hearing loss in the early stage, which gets worse gradually with the progress of the disease. At least 1 pure tone audiometry is sensorineural hearing loss, and auditory revitalization can occur.
3	Accompanied by tinnitus and/or fullness of ears.
4	Vertigo caused by other diseases, such as benign paroxysmal positional vertigo, labyrinthitis, vestibular neuritis, drug toxic vertigo, sudden deafness, vertebrobasilar insufficiency and intracranial space occupying lesions were excluded.

inner ear membrane labyrinth in these countries and regions. Based on the above ideas, following the publication "Clinical Application of Gadolinium Enhancement in Patients with Meniere Disease under the Condition of 1.5T MRI,"[1] the author designed a comparative study for 1.5T MRI and 3.0T MRI gadolinium enhancement of inner ear. The purpose is to further explore the practicality and maneuverability of 1.5T MRI inner ear gadolinium in the diagnosis of inner ear membrane labyrinth hydrops and to further expand the use of 1.5T MRI gadolinium enhancement of inner ear in the world.

METHODS

Research Objects

The experimental group selected 25 patients with Meniere's disease who were admitted to the outpatient department of Hospital A from April 2017 to October 2020. Among them, 13 were males and 12 were females, with an average age of 60.0 (34-67) years old; the control group consisted of 51 Meniere's disease patients who were admitted to Hospital B from March 2010 to February 2011 and whose data were published in the *Chinese Medical Journal* in 2011, including 22 males and 29 females, with an average age of 47.6 (19-69) years old.[2] The 2 groups of Meniere's disease cases were selected according to the diagnostic criteria of Meniere's disease at the Guiyang Conference of the Chinese Medical Association in 2006,[3] and the diagnostic criteria are shown in Table 1. There was no abnormality in the tympanic membranous of the external auditory meatus of all patients, and gadolinium contrast agent was injected into the tympanum of both ears within 1 week of the last episode of vertigo, and there was no contraindication to gadolinium tympanum injection. This study was conducted after review and approval by the Ethics Committee of People's Hospital of Ordos Dongsheng District (2017-s001). Before proceeding, each patient's consent was obtained and the informed consent form was signed.

Inspection Methods

Using our hospital's German SIEMENS Avanto 1.5T MRI, each selected patient was scanned twice with an MRI-related sequence, 12-channel head coil collection, with an interval of 24 hours. The scanning sequence is as follows: (1) fast spin-echo sequence (3D-Sampling Perfection with Application -optimized Contrasts using different flip-angle Evolution Turbo Spin Echo (SPACE-TSE)) with optimized contrast sampling of 3-dimensional multiple inversion angles, as a reference for labyrinth shape, parameters: Repetition Time (TR) 1000 ms, Echo Time (TE) 132 ms, spatial resolution 0.7 mm × 0.7 mm × 1 mm, volume acquisition in all directions, scanning time 256 s and (2) liquid suppression reversal recovery sequence (3D-SPACE-FLAIR) using 3-dimensional multi-inversion angle optimization contrast sampling, scanning parameters: TR 6000 ms, TE 388 ms, Inversion Time (TI) 2100 ms, scan time 332s, spatial resolution 0.7mm × 0.7 mm × 1 mm, volume acquisition in all directions, scan time 338 s, including 3D-SPACE-TSE and 3D-SPACE-FLAIR. The scanning range level is the same, making the 2 comparable at the same level. The control group uses a 3.0T magnetic resonance machine (Simense Veri, Germany), 16-channel head coil acquisition, and the scan sequence and scan time are the same as the experimental group, and the spatial resolution is slightly different.[2]

1. All patients in the experimental group were examined by axial 3D FLAIR sequence MRI before tympanic injection and then each patient's head was asked to tilt back about 15-20° under otoendoscopy. In order to ensure that the injection in the tympanic chamber does not flow out, a relatively safe 0.5-0.8 mL of meglumine gadolinate dilution was injected above the tympanic membrane. The diluent ratio is gadopentetate meglumine injection/0.9% saline = 1 : 7. The patient was instructed to keep the head back at 15° for 1 hour and then return to the ward to lie on the back for 6 hours or longer in the head-up position and then perform a second MRI examination at the same time 24 hours later.
2. Working independently, 2 experienced MRI physicians will observe and calculate the 3D-SPACE-FLAIR sequence and 3D-SPACE-TSE sequence before and after 24 hours of gadolinium injection in the tympanum of all patients in the experimental group. If their opinions are consistent, a conclusion is reached; if there is a disagreement, a third physician will be asked to make the calculation again; for the control group and the Nakashima 3-level quantification method[4] can be used to measure the endolymphatic area and ipsilateral vestibular area

MAIN POINTS

- The contrast study of gadolinium enhancement in the inner ear by tympanic injection of 1.5T and 3.0T magnetic resonance imaging (MRI) shows that gadolinium enhancement in the inner ear of 1.5T MRI has the same diagnostic value as that of 3.0T.
- In order to solve the problem of routine control study, a group of gadolinium-enhanced cases of 3.0T MRI inner ear that were published in authoritative journals was selected as the control group.
- This study provides academic support for hospitals in developing countries and underdeveloped areas with only 1.5T MRI in the world to carry out the diagnostic technique for membrane labyrinthine hydrops in the inner ear using 1.5T MRI gadolinium enhancement.

Table 2. Classification of Endolymph Hydrops

Degree of Hydrops	Vestibular (Area Ratio)[a]	Cochlea
No water accumulation/mild water accumulation	≤1/3	No Reissner's membranous shift
Moderate water accumulation	>1/3-1/2	Reissner's membrane is shifted and the endolymphatic space does not extend beyond the vestibular scala
Heavy water accumulation	>eav	Reissner's membrane shifts to the endolymphatic space beyond the vestibular scala

An area ratio is the area of low signal area/(area of low signal area + area of high signal area.

at horizontal semicircular canal level and the ratio R can be obtained. R = low signal area/(low signal area + high signal area) × 100%, referring to Nakshima and other standards, R > 33.3% can be diagnosed as membranous labyrinth hydrops. Table 2 shows the results.

3. Statistical Package for the Social Sciences 17.0 was used for data analysis, and χ^2 test was performed to compare the experimental group and the control group; the test level (the freedom degree is 1), $\alpha = 0.05$ (samples are 76 cases). With $\chi^2 = 0.0003$ and $P > .05$, it is considered that the data of 2 groups are not statistically significant, and there is no difference in the water accumulation rate between the experimental group and the control group.

RESULTS

Results of Gadolinium Enhancement in the Experimental Group

The 25 patients in the experimental group obtained ideal MR images. According to the calculation of Nakashima method,[4] R value of 25 is considered as confirmed Meniere's disease case. There were 9 cases whose value R is between 33.3% and 50% (mild water accumulation), 15 cases whose value R is >50% (severe water accumulation), 1 case whose value R is < 3.3% (no water accumulation). In total, there were 24 cases being calculated as having water accumulation, and the water accumulation rate is 96% (24/25). One of the right ear patients is a 50-year-old male. The 3D-SPACE-TSE sequence in the same layer of the inner ear is shown in Figure 1, and the 3D-FLAIR sequence before and after tympanic injection of gadolinium for 24 hours is shown in Figures 2 and 3.

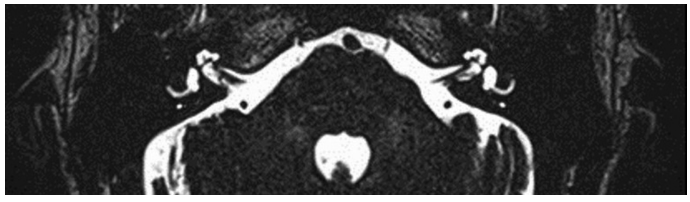

Figure 1. Axial 3D-SPACE-TSE images show Normal inner ear structure.

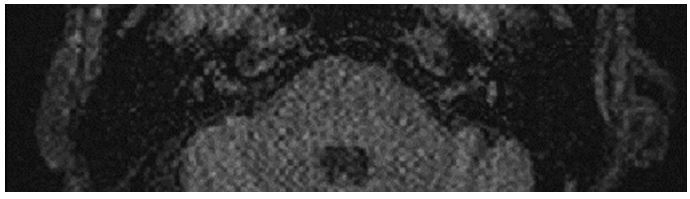

Figure 2. Images of axial 3D-FLAIR before gadolinium injection in the tympanum.

Results of Gadolinium Enhancement in the Control Group

The 51 cases of Meniere's disease were calculated according to the Nakashima method[4] and found that the value R of 49 cases was >33.3%, indicating that the water accumulation rate was 96.1% (49/51). There was no difference between the experimental group and the control group, which was not statistically significant ($P > .05$). After the experimental group and the control group were injected with gadolinium, a small number of patients experienced transient vertigo due to the low temperature of the liquid medicine. No complications such as infection, perforation, allergies, etc. were seen in all patients. One of the right ear patients is a 41-year-old male. The 3D-SPACE-TSE sequence Maximum Intensity Projection (MIP) reconstruction is shown in Figure 4, the 3D-SPC-IR-FLAIR sequence MIP reconstruction is shown in Figure 5, and the enlarged inner ear vestibular balloon is shown in Figure 6.

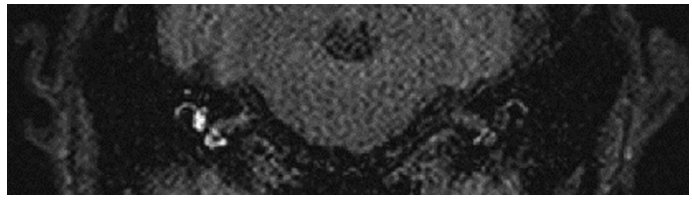

Figure 3. Axial 3D-FLAIR images 24 hours after gadolinium injection in the tympanum showing cochlear vestibular hydrops in the right inner ear. The 3 images are generated from same layer in the patient's inner ear and the layer thickness is 1 mm.

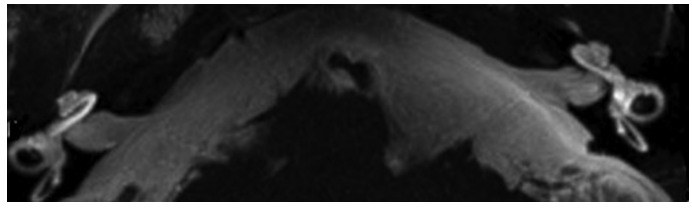

Figure 4. Three-dimensional SPACE-TSE sequence MIP reconstruction image. The morphological signals of the bilateral labyrinth are symmetrical and no abnormalities are seen.

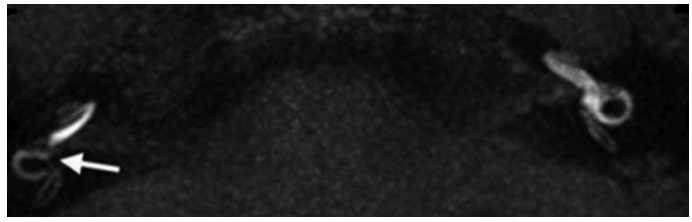

Figure 5. Three-dimensional SPC-IR-FLAIR sequence MIP reconstruction image. The right cochlear duct is small and the vestibular signal is obviously low.

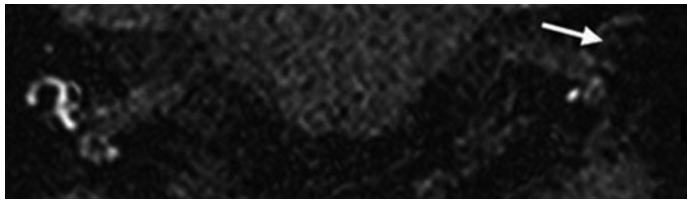

Figure 6. Images of axial 3D-SPC-IR-FLAIR. Original thin layer diagram of Figure 5 showing the expansion of the vestibular balloon of the inner ear.

CONCLUSION

The article "Clinical Application of Gadolinium Enhancement in Patients with Meniere Disease under the Condition of 1.5T MRI" has separately explained the feasibility of 1.5T MRI gadolinium enhancement in Meniere membranous hydrops.[1] The purpose of this article is to compare and statistically analyze the 1.5T MRI and 3.0T MRI gadolinium enhancement of the inner ear to further illustrate the practicality and universality of 1.5T MRI gadolinium enhancement in the diagnosis of Meniere's disease.

In this study, the 1.5T MRI and 3.0T MRI use the same sequence. The difference is that 1.5T MRI has the ability to capture signals and the signal-to-noise ratio is lower than 3.0T MRI. The 3D-SPACE-TSE and 3D-FLAIR sequence scans are appropriately increased to 1 mm in thickness to obtain the above pictures. Therefore, only the following technicians and equipment are essential to develop the inner ear gadolinium enhancement technology: (1) otology technicians who are proficient in otoscope technology, (2) imaging technicians who are proficient in MRI operation technology and image reading, and (3) otoscopes system and MRI equipment above 1.5T.

In this study, the experimental group and the control group had basically the same dosing method through the tympanum. Both groups were injected with the gadolinium diluent solution into the tympanum via the external auditory canal tympanic membranous. In the meantime, patients were asked to maintain a proper head position and wait for 24 hours to be scanned by 3D-SPACE-TSE and 3D-FLAIR sequence again. The 3D-SPACE-TSE and 3D-FLAIR sequence scanning can obtain clearer images of inner ear outer lymphatic enhancement and then evaluate according to the Nakashima method and finally know whether there is membranous labyrinth hydrops.

This control study further shows that the inner ear gadolinium enhancement technique is not a unique and difficult technique under 3.0T MRI conditions. Clear enhancement images can also be obtained under 1.5T MRI conditions, and this technique can also be carried out.

At present, the world economic development is extremely unbalanced. 3.0T MRI is relatively popular in developed countries such as Europe and the United States. Most of them can use 3.0T MRI to carry out inner ear gadolinium enhancement. However, there are only 1.5T MRI in secondary hospitals in China and hospitals in less-developed countries and regions such as Africa, and these countries and regions account for the majority in the world. Therefore, if inner ear gadolinium enhancement can be widely carried out in these countries and regions, the patients with Meniere's disease in these countries and regions will be widely benefited.

The conventional controlled study was performed on the same group of Meniere patients with 1.5T MRI and 3.0T MRI tympanic chamber injection gadolinium enhancement scans, so as to statistically process their statistical results and showed that 1.5T MRI and 3.0T MRI are effective for Meniere's diseas. It is also used to evaluate whether the detection rate and clinical value of EH are different. However, in actual operation, it is difficult to convince a group of patients to do MRI scans 4 times due to the relatively long time of MRI scans, high noise and vibration, and discomfort in closed lying. Therefore, in order to solve the above-mentioned problems, this study conceived that 2 groups of Meniere patients from different hospitals were selected for a controlled study. The control group is a group of cases that have been published in authoritative journals, and the diagnosis of this group of cases is strictly based on the 2006 Chinese Medical Association Guiyang Conference Meniere Disease diagnosis criteria, and the pictures of this group of cases are stable and will not change with time. Hence, the comparison between the control group and the experimental group in this study has a certain reference value. This not only solves the problems in the research method but also shows that the value and significance of 1.5T MRI and 3.0T MRI are the same in the clinical diagnosis of Meniere's disease through statistical analysis of the examination results.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of People's Hospital of Ordos Dongsheng District (Approval no: 2017-s001).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Y.H., X.C.; Design – Y.H., X.C.; Supervision – J.Z.; Funding – Y.H., L.L., J.Z.; Materials – Y.H., L.L.; Data Collection and/or Processing – Y.H., X.C., L.L., X.G., L.W., X.D., W.F; Analysis and/or Interpretation – Y.H., X.C., L.L.; Literature Review – Y.H.; Writing Manuscript – Y.H.; Critical Review – X.C., L.L.

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Declaration of Interests: The authors declare that they have no conflict of interest.

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