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Labyrinthine Artery Detection in Patients with Idiopathic Sudden Sensorineural Hearing Loss by 7-T MRI

Hiroaki Sato, MD, PhD1, and Kazuaki Kawagishi, MD1

Abstract

Objective. To compare the detection rates of the labyrinthine artery in subjects with idiopathic sudden sensorineural hearing loss (ISSHL) and in normal-hearing controls using 7-T magnetic resonance imaging (MRI).

Study Design. Cross-sectional study.

Setting. Tertiary referral center.

Subjects and Methods. In 18 patients (9 males, 9 females) with ISSHL and 32 volunteers (21 males, 11 females) with normal hearing, 7-T MRI (Discovery MR950; GE Healthcare, Milwaukee, Wisconsin) was performed with the 3-dimensional time-of-flight spoiled gradient echo (3D TOF SPGR) sequence to compare the detection rates of the labyrinthine artery.

Results. The MRI scans were performed from 3 to 54 days after onset. Of the 18 patients with ISSHL, 8 showed complete recovery, 9 showed partial recovery, and the rest showed no recovery. The labyrinthine artery was depicted in 36 of 36 ears (100%) in the ISSHL group and 63 of 64 (98.4%) ears in the normal-hearing group, with no significant difference in detection rates.

Conclusion. To our knowledge, the present study is the first to report depiction of the labyrinthine artery by 7-T MRI. These preliminary results indicate occlusion of the labyrinthine artery would be rare in the pathogenesis of ISSHL, and they also demonstrate that the labyrinthine artery could be detected by ultra-high-field MRI.

Keywords
labyrinthine artery, 7-T MRI, idiopathic sudden sensorineural hearing loss

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The pathogenesis of idiopathic sudden sensorineural hearing loss (ISSHL) is still unknown, but an inner ear circulatory disturbance has been considered one possible pathogenesis, comparable to cardiovascular diseases such as stroke or myocardial infarction. A recent meta-analysis of the cardiovascular risk factors for ISSHL indicated a positive association between cardiovascular risk factors and ISSHL.1 It is also well known that the inner ear can be infarcted in patients with anterior inferior cerebellar artery (AICA) stroke, because the labyrinthine artery, which usually branches from the AICA, is an end artery.2-4 Cases of labyrinthine infarction secondary to AICA occlusion are often accompanied by clinical symptoms other than hearing loss, including Horner’s syndrome, diplopia, ipsilateral facial weakness, vertigo, and ataxia.4 However, AICA infarction5 and labyrinthine artery infarction6 exhibiting only deafness and vertigo have also been reported, although rarely.

The labyrinthine artery is very difficult to depict due to its small diameter.7,8 However, ultra-high-field magnetic resonance imaging (MRI), such as 7-T MRI, may have the potential to detect the labyrinthine artery because of its high signal-to-noise ratio, being able to provide fine images with the resolution of a few hundred microns. In the present study, depiction of the labyrinthine artery was attempted using 7-T MRI with the 3-dimensional (3D) time-of-flight spoiled gradient echo (3D TOF SPGR) sequence, and the detection rates were compared between normal-hearing controls and patients with ISSHL.

Subjects and Methods

Subjects

This study included 19 consecutive patients with ISSHL (male-to-female ratio of 9:10; age range, 25-75 years; mean [SD] age, 53.2 [17.0] years) and 32 normal-hearing controls without a history of hearing impairment (male-to-female ratio of 8:6; age range, 21-55 years; mean [SD] age, 27.6

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The diagnosis of ISSHL was based on the criteria of the Sudden Deafness Research Committee of the Japanese Ministry of Health, Labor and Welfare (Table 1). All subjects met the audiometric hearing criteria of more than 30 dB affecting at least 3 consecutive frequencies. One patient (65-year-old woman) with ISSHL was excluded from this study because evaluation of the labyrinthine artery was not possible due to motion artifact. Therefore, 18 patients with ISSHL and 32 normal-hearing controls were enrolled in the present study.

All patients with ISSHL were given oral administration of corticosteroid (betamethasone 4 mg with tapering), vitamin B12, and adenosine triphosphate for 12 days, as well as intravenous administration of low-molecular-weight dextran for 5 days. Hyperbaric oxygen therapy was used simultaneously for 11 of 18 patients with ISSHL.

### Hearing Level Evaluation

Hearing levels were evaluated at the initial and final visits. The final visit varied from 3 to 231 days (mean [SD], 94.3 [97.0] days) from onset. When the patients did not respond to the maximum sound level generated by the audiometer, the threshold was defined as 5 dB more than the maximum level. Recovery was classified into 3 categories: complete (PTA within 10 dB of the initial hearing level or within 10 dB of the hearing level of the unaffected ear), partial (PTA within 50% of the initial hearing level or 10-dB improvement of the hearing level), and no recovery (<10-dB improvement relative to the initial hearing level).9

### Scan Parameters of MRI

A 7-T MRI scanner (Discovery MR950; GE Healthcare, Milwaukee, Wisconsin) with transmission and 32-channel receive head coils was used. Acquisition parameters for 3D TOF SPGR magnetic resonance angiography (MRA) were as follows: repetition time, 19 ms; bandwidth, 20.83 kHz; echo time, 4.3 ms; flip angle, 15 degrees; field of view (FOV), 12 × 12 cm²; matrix size, 512 × 512; slice interval, 0.3 mm (after zero-fill interpolation [ZIP]); number of slices, 120; number of excitations [NEX], 2; no phase wrap; and acquisition time, 20 minutes 49 seconds. Imaging was first performed without contrast enhancement and then performed using contrast with 0.2 mL/kg gadodiamide hydrate (Omniscan; Daiichi-Sankyo, Tokyo, Japan).

This study was approved by the Ethics Committee at Iwate Medical University (H24-67). All subjects provided written informed consent.

### Evaluation of the Labyrinthine Artery

Visibility of the labyrinthine artery was defined as at least 1 linear structure in the internal auditory canal depicted with and without contrast media (Omniscan), which appeared to be separated from the AICA. Visibility of the labyrinthine artery was evaluated by both authors (H.S. and K.K.) independently.

### Data Analysis

To compare the detection rates of the labyrinthine artery between controls and patients with ISSHL, the \( \chi^2 \) test was used. \( P \) values <.05 were considered significant.

### Results

Magnetic resonance images of the labyrinthine artery are shown in Figure 1. The artery could be clearly seen in the anterior aspect of the internal auditory canal (left ear of a 30-year-old man, normal control; case 2). It was clearly detected both with and without contrast media (Omniscan), which appeared to be separated from the AICA. Visibility of the labyrinthine artery was evaluated by both authors (H.S. and K.K.) independently.

### Figure 1. Comparison of magnetic resonance (MR) images of the labyrinthine artery with and without gadodiamide (Gd) enhancement (left ear of a 30-year-old man, normal control; case 2). The labyrinthine artery (arrowhead) can be clearly depicted on MR images with (right) and without (left) Gd enhancement.
Most of the subjects experienced transient dizziness when being moved into the gantry; however, no specific hazards were noted after the scanning. No subject was unable to be scanned due to the transient dizziness.

In 32 normal controls, the labyrinthine artery was depicted in 63 of 64 ears (98.4%). In 18 patients with ISSHL, it was detected in 36 of 36 ears (100%). There was no significant difference in detection rates between the 32 normal-hearing controls and the 18 patients with ISSHL ($P = .769$). Results of the visibility of the labyrinthine artery correlated well among authors. The locations of the labyrinthine arteries were mainly in the anterior aspect of the internal auditory canal. In 32 normal-hearing controls, it lay in the anterior aspect of the internal acoustic canal in 51 ears, in the middle aspect in 8 ears, and in the posterior aspect in 14 ears. Multiple positioned additional labyrinthine arteries (biarterial type) were observed in 8 of 64 ears. The labyrinthine artery lay in the anterior aspect in 32 of 36 ears in 18 patients with ISSHL, in the middle aspect in 5 ears, and in the posterior aspect in 3 ears. The biarterial type (Figure 3, right ear) was observed in 5 patients.

Demographic, audiologic, and MRI data from 18 patients with ISSHL are listed in Table 2. Intervals from onset of MRI examination varied from 3 to 54 days. As for hearing outcome, 8 patients showed complete recovery (CR), 9 patients had partial recovery (PR), and 1 patient had no recovery (NR). Hypertension, hyperlipidemia, and diabetes mellitus were observed in 4, 1, and 2 of the 18 patients with ISSHL, respectively. The labyrinthine artery was detected both with and without contrast media in all subjects.

**Discussion**

The labyrinthine artery usually arises from the apex of the loop of the AICA. It runs along the upper groove of the eighth cranial nerve toward the fundus of the internal acoustic meatus. In about 10% of individuals, it runs under the surface of the eighth cranial nerve in the internal acoustic meatus.10 In the present study, most labyrinthine arteries were depicted in the anterior aspect of the internal auditory canal, the location of which coincides with the previous human temporal bone observations.10

Even a short period of ischemia can cause inner ear damage because the labyrinthine artery and its branches are end arteries with minimal collaterals from other major arterial branches.11 With circulatory impairment of the AICA or the labyrinthine artery, cochlear symptoms, predominantly hearing loss, usually develop, and vertigo often occurs. Although it is rare, sudden hearing loss associated with vertigo in a patient with AICA occlusion without neurological deficits other than the eighth cranial nerve has been reported.5 Kim et al6 reported a patient who exhibited sudden hearing loss and vertigo, who then died 7 years later due to myocardial infarction. They found degeneration of the inner ear sensory epithelium as a result of reduced perfusion of the labyrinthine artery due to arteriosclerosis on postmortem examination. However, these reports lack direct evidence of vascular occlusion on imaging. To resolve this issue, visualization of the labyrinthine artery is absolutely necessary.

In the present study, 7-T MRI examinations with and without gadodiamide contrast were performed using the 3D TOF SPGR protocol. This ultra-high-field MRI unit enabled imaging of the labyrinthine artery, which until now has not been possible to depict. As a result, the depiction rate of the labyrinthine artery in the 32 normal-hearing controls was 98.4% (63 of 64 ears), and that in the 18 patients with ISSHL was 100% (36 of 36 ears). The detection rates and the magnetic resonance images obtained were basically the same both with and without contrast media. Therefore, contrast media is not necessary for the depiction of the labyrinthine artery. Extremely high depiction rates in the present study made it possible to evaluate the presence of a circulatory disturbance of the labyrinthine artery to some extent.

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The labyrinthine artery could not be depicted in 1 ear of the affected patients, whereas it was depicted in 98.4% (63 of 64 ears) of normal-hearing controls. This was attributed to the variation in diameters of the labyrinthine artery. Its diameter has been observed in only 1 of 17 cases with ISSHL.12

The present study has a few limitations. First, the interval between the onset of hearing loss and the MRI examination ranged from 3 to 54 days. Thus, the magnetic resonance images obtained in this study do not reflect the images just after the onset of hearing loss. In other words, there remains the possibility that a transient ischemic event due to vasospasm could have been missed. Vasospasm might occur in the labyrinthine artery because it has a muscular media.13,14 Second, other small arteries that supply the inner ear circulation, such as the cochlear artery, were not evaluated. Third, the sample size was small to conclude whether an inner ear circulatory disturbance is present in ISSHL. However, an association between visibility of the labyrinthine artery and cardiovascular risk factors could not be observed.

The present study has clinical significance in offering a useful method to evaluate circulatory disturbances of the labyrinthine artery.

**Conclusion**

The present study is the first to report depiction of the labyrinthine artery by 7-T MRI. The depiction rate of the labyrinthine artery was 98.4% (63 of 64 ears) in 32 normal-hearing controls and 100% (36 of 36 ears) in 18 patients with ISSHL. These preliminary results indicate that occlusion of the labyrinthine artery would be rare in the pathogenesis of
ISSHL, and they also demonstrate that the labyrinthine artery could be detected by ultra-high-field MRI.

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Author Contributions
Hiroaki Sato, conception and design, main revision of the manuscript; Kazuaki Kawagishi, acquisition of data, analysis.

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