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審査学位論文
（博 士）

Limited detection of the internal auditory artery by 3-T MRI

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Abstract

Although disturbance of inner ear blood flow has been considered to be one of the causes of idiopathic sudden sensorineural hearing loss, imaging of the internal auditory artery (IAA) has not been reported to date. The aim of this study was to determine whether the IAA in subjects with normal hearing could be imaged using a three-tesla magnetic resonance image (3-T MR). Twelve volunteers with normal hearing underwent 3-T MR imaging with fast spoiled gradient recalled acquisition in the steady state (FSPGR) sequence to image the IAA. Of 24 ears, the IAA and the common cochlear artery (CCA) were identified in 7 (29.2%), and 10 (41.7%), respectively. The IAA and the CCA were bilaterally identified in 1 (4.2%) and 2 subjects (8.3%), respectively. The present study is the first report regarding demonstration of the IAA and shows that the IAA was imaged in 30% of subjects with normal hearing using 3-T MR.

Key words

3-T MR imaging, internal auditory artery, detection rate, healthy subjects

Ⅰ. Introduction

The etiology of idiopathic sudden sensorineural hearing loss (ISSNHL) is still unknown, and the presumed causes include a viral infection[1-4], vascular disorders[5.6], or NF-κB activation due to stress[6]. In the literature on temporal bone histologic findings in patents with ISSNHL, vascular insult was found in only 3 of 44 cases[7]. Labyrinthine artery infarction[8] and anterior inferior cerebellar artery (AICA) infarction exhibiting only deafness and vertigo[9] have also been reported, although they are rare. However, because the internal auditory artery (IAA) is difficult to depict due to its small diameter, evaluation of inner ear circulatory disturbances in ISSNHL has not been reported. The IAA is an end artery of the inner ear and, in the internal auditory canal, anatomically venous drainage is completely separated from the arterial system. Therefore, identification of the IAA and its branches entering into the inner ear may be easy if these arteries are imaged by high-field magnetic resonance (MR) imaging. The aim of this study was to assess normal anatomy of the IAA on 3-T MR imaging in subjects with normal hearing before evaluating IAA circulation in patients with ISSNHL.

Ⅱ. Methods

This study included 12 adult male volunteers without a history of hearing impairment. Their ages ranged from 27 to 43 years, with a mean age of 33.3 years. The study was performed at the High Field MRI Research Institute of Iwate Medical University (Takizawa, Iwate). MR imaging was performed by fast spoiled gradient recalled acquisition in the steady state (FSPGR) sequence using 3-T MRI unit (Signa Excite HD, GE Medical Systems) and an 8-channel phased array coil. For imaging protocols, from among many attempted scan parameters, acquisition times that provided best results were selected. There were two protocols.

Protocol 1 included: matrix size 1024 × 512; slice thickness, 1.0 mm (0.5 mm overlap); field of view [FOV], 15 × 15 cm; number of excitations [NEX], 3; repetition time [TR]/echo time [TE], 19. 3/4.1; acquisiton time: 31 minutes 42 seconds. Protocol 2 included: matrix size 1024 × 512; slice thickness, 0.8 mm (0.4 mm overlap); FOV, 20 × 18 cm; NEX, 2; TR/TE 19.1/3.8; acquisition time: 18 minutes 50 seconds. Imaging was performed using contrast with gadodiamide hydrate (Omniscan®, Daiichi-Sankyo, Japan, 0.2 ml/kg).

Demonstration of the IAA was defined as at least one linear structure in the internal auditory canal (IAC) on the scan with contrast media, and it appeared to be separated from the AICA. Demonstration of the CCA was defined as a linear structure entering from the IAC to the modiolus of the cochlea.

Detection rates of the IAA and CCA were evaluated by 2 of the authors (A.M. & T.N.). To compare the detection rates of the IAA and CCA between protocol 1 and 2, Fisher's exact probability test was used. *P* values <.05 were considered significant.

This study was approved by the Ethics Committee at Iwate Medical University (H21-118). All subjects provided written, informed consent.

Ⅲ. Results

Table 1 summarizes the results. Of 12 subjects, 4 and 8 subjects underwent protocol 1 and 2 respectively. In protocol 1, the IAA was depicted in 2 of 8 ears (25%), and the CCA was depicted in 3 of 8 ears (37.5%). Under protocol 2, the IAA was depicted in 5 of 16 ears (31.3%), and the CCA was depicted in 7 of 16 ears (43.8%). There were no differences in detection rates of the IAA and CCA between these two protocols (IAA; *P*=0.572, CCA; *P*=0.561). Overall, the IAA was depicted in 7 of 24 ears (29.2%), and the CCA was depicted in 10 of 24 ears (41.7%). No significant difference was noted between the detection rates between the IAA and the CCA. (*P*=0.365). The IAA and the CCA were bilaterally identified in 1 (4.2%) and 2 subjects (8.3%), respectively. Figure 1 shows a typical MR image of the IAA and CCA. The main cochlear artery and vestibulocochlear artery were depicted in 2 subjects and 1 subject, respectively (Figs. 2, 3).

Ⅳ. Discussion

The IAA is a branch of the AICA with the opening of the internal auditory canal. The anterior vestibular artery (AVA) and the common cochlear artery (CCA) are branches of the IAA ~~to~~ providing nutrition to the cochlea[10)]. Because the CCA is a terminal artery[11)] , loss of supporting cells in the cochlea/vestibule and degeneration of hair cells occurs when the IAA is experimentally occluded in animal models[12,13)] . With circulatory impairment of the IAA and CCA, cochlear symptoms, predominantly hearing loss, usually develop, and vertigo often occurs. Lee et al.[9)] reported a patient with AICA occlusion presenting sudden with hearing loss associated with vertigo. Kim et al.[8)] reported a patient who had sudden hearing loss and vertigo, with persistent severe deafness, and then died 7 years later due to myocardial infarction. On postmortem examination, they found degeneration of the cochlear/vestibular sensory epithelium as a result of reduced IAA perfusion due to arteriosclerosis. In addition, Belal et al.[14)] reported fibrosis of the cochlear/vestibular labyrinth and proliferation of osteoid tissue due to IAA injury in a patient who had undergone trans-middle cranial fossa surgery for Ménière's disease and acoustic neuroma.

On 1.5-T MR angiography, the IAA is usually not depicted. By improving the signal-to-noise ratio (SNR) with a 3-T MR imager, the brain vasculature is depicted in more detail. The 3-T MR imager could provide fine useful venous images with a resolution of 200 μm (diameter), but it is not clear whether small arteries such as the IAA and CCA could be better depicted.

In the present study, imaging was performed with a 3-T MR imager using gadolinium contrast and an FSPGR protocol, allowing fine vascular imaging using thinner slices. This may make detection imaging of smaller vessels such as the IAA possible. Depiction rates of the IAA and the CCA were 29.2%, and 41.7%, respectively. The present study was the first report regarding imaging of the IAA in humans using a 3-T MR imager. These depiction rates were still not satisfactory for clinical diagnosis of inner ear circulatory disturbances, and these low depiction rates may be caused by frequent variations of the vertebrobasilar artery system and its branches. The IAA was commonly a branch of the AICA, but it may be a branch of the posterior inferior cerebellar artery, other cerebellar arteries, or the basilar artery[10,15-21] .

In all our subjects in whom depiction of the IAA was possible, the IAA was a branch of the AICA. The spatial relationship of the three arterial branches of the IAA (the anterior vestibular artery, the cochlear artery, and vestibulocochlear artery) and the vestibulocochlear nerve within the fundus of the internal auditory canal is usually constant[22] . However, near the opening of the internal auditory meatus, the IAA is often two arteries and the spatial relationship between the artery and the nerve varies. In addition, absence of the IAA and CCA, 2 to 3 IAAs, branching into 4 vessels, and tortuosity of a single artery have also been reported[23] . These are limitations in imaging of the IAA as a single linear structure. In contrast, the CCA usually traverses the modiolus and its variations are considerably less than those of the IAA, resulting in a higher detection rate of the CCA.

In addition, diameters of the arteries in the internal auditory canal are considerably different between the left and right sides. Internal diameters of the arteries located in the internal auditory canal also vary, which may affect imaging of these arteries on MR. For example, in a report by Ishii[9] (Table 2), the internal diameter of the labyrinthine artery ranged from a maximum of 140 μm to a minimum of 68 μm. In a report by Levin, the range was 200-900 μm. Smaller labyrinthine arteries may not be depicted. In the present study, differences in depiction between the left and right arteries were observed even within the same subjects. These were probably due to the above mentioned anatomical variations of the IAA.

The present study is the first report regarding MR imaging detection of the IAA with 3-T MR using FSPGR. The depiction rate of the IAA is low, only 29.2%, which is still insufficient for evaluation of hemodynamic impairment in sudden hearing loss. However, in the future, with technical improvement, evaluation of inner ear circulatory disturbances in sudden hearing loss may be possible.

Ⅴ. Conclusion

With 3-T MR using FSPGR in 12 normal hearing volunteer subjects (24 ears), the depiction rates of the IAA and CCA were 29.2% and 41.7%, respectively. The main cochlear artery and vestibulocochlear artery were seen in 2 subjects and 1 subject, respectively. Future technical development will help in assessing inner ear circulatory disturbances in sudden hearing loss.

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Conflict of Interest statement: Atsuhiro Mizukawa and the other co-authors have no conflict of interest.

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3T-MRIによる内耳動脈の描出の検討

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抄録

突発性難聴の原因の 1 つとして内耳血流障害が挙げられているが、これまでに内耳動脈を画像的に評価した報告はみられない。本研究の目的は聴覚正常者を対象として 3T-MRI により内耳動脈の描出が可能かを評価することである。3T-MRI を用いて fast spoiled gradient recalled acquisition in the steady state（FSPGR）法にて、聴覚の正常なボランティア 12 名に対し、内耳動脈の描出を試みた。内耳動脈は 24 耳中 7 耳(29.2%)、総蝸牛動脈は 24 耳中 10 耳(41.7%)で描出された。このうち両側描出されたのは内耳動脈が 1 例(4.2%)、総蝸牛動脈が 2 例(8.3%)であった。本報告は内耳動脈を 3T-MRI で描出し得た、最初の報告であり、聴覚正常者の３０％で内耳道脈が描出できた。

Figure legends

Fig. 1. The linear structure running through the internal auditory canal indicates internal auditory artery (IAA), which is a branch of the AICA. From here, the common cochlear artery (CCA) courses along the modiolus.

Fig. 2. The linear structure is considered to be the main cochlear artery (MCA), which is a branch of the CCA.

Fig. 3. The vestibulocochlear artery is depicted from the CCA to the main cochlear artery. 1)ICC:Internal auditory artery; 2)CCA:Common cochlear artery; 3)VCA Vestibulocochlear artery; 4) MCA: main cochlear artery

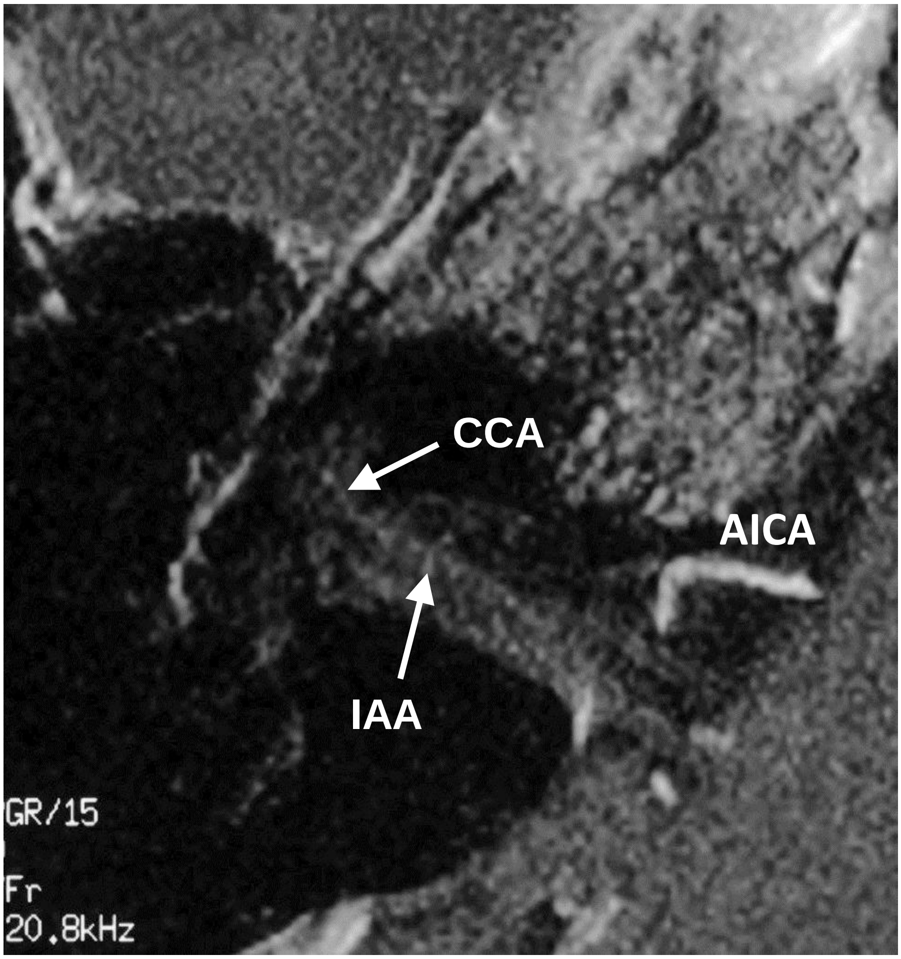

Figure 1
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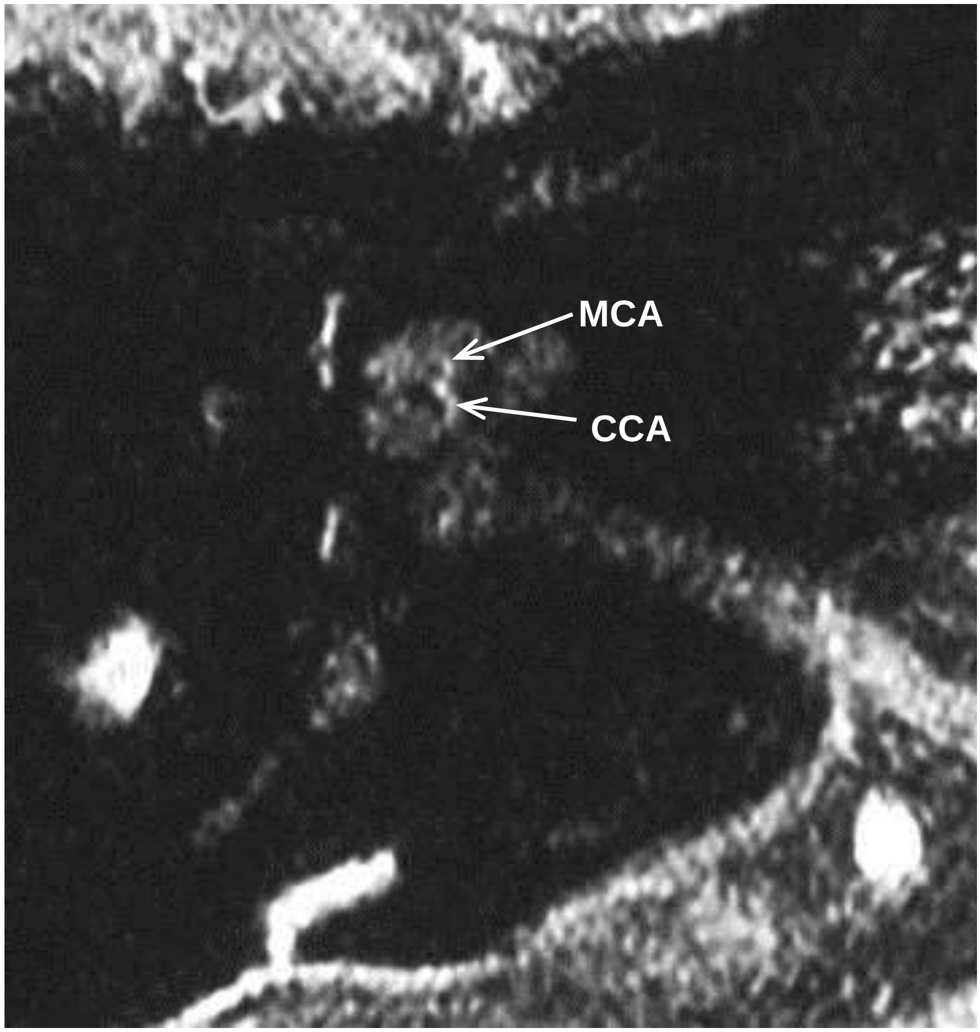

Figure 2
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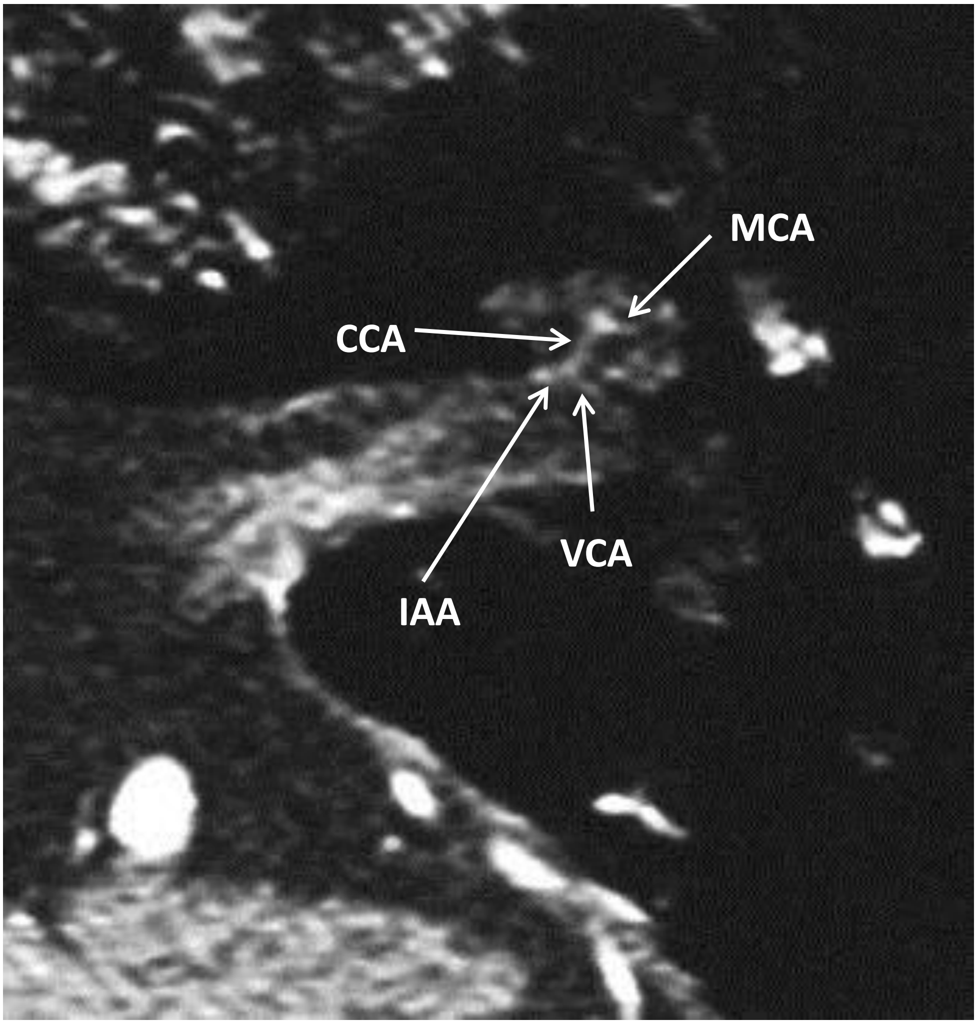

Figure 3
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Table 1 Depiction results

Imaging protocol	Age (years)	Sex	Labyrinthine artery R	Labyrinthine artery L	Common cochlear artery R	Common cochlear artery L
Protocol 1	35	M	＋	−	＋	−
	35	M	＋	−	＋	−
	35	M	−	−	＋	−
	34	M	−	−	−	−
Protocol 2	37	M	＋	＋	＋	＋
	31	M	−	−	−	＋
	28	M	−	−	＋	−
	43	M	−	−	−	−
	36	M	−	＋	＋	＋
	31	M	＋	−	−	−
	27	M	−	＋	−	−
	28	M	−	−	−	＋

＋: depicted −: not depicted

Table 1.
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Table 2. Outer diameter (inner diameter)* of the arteries of the internal auditory canal (Cited from Ref. 10)

	Right	Left	Mean	Maximum	Minimum
Labyrinthine A.	**141 (72)**	**173 (82)**	**155 (76)**	**245 (140)**	**100 (68)**
Common cochlear A.	**122 (64)**	**124 (64)**	**123 (64)**	**175 (70)**	**74 (46)**
Main cochlear A.	**82 (41)**	**86 (43)**	**84 (42)**	**125 (68)**	**50 (25)**
Vestibulocochlear A.	**95 (46)**	**107 (48)**	**101 (47)**	**132 (88)**	**64 (40)**
Anterior vestibular A.	**79 (33)**	**85 (40)**	**82 (37)**	**116 (60)**	**50 (25)**

*all diameters are in μm

Table 2.
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