Journal of Otology 18 (2023) 193–198

Contents lists available at ScienceDirect

Journal of Otology

journal homepage: www.journals.elsevier.com/journal-of-otology/

Location of the AICA influences the severity but not occurrence of ISSNHL: A reappraisal using high-resolution 3 T MRI

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ARTICLE INFO

Article history:
Received 31 May 2023
Received in revised form
8 July 2023
Accepted 10 July 2023

Keywords:
Idiopathic sudden sensorineural hearing loss
Anterior inferior cerebellar artery
Anatomy
Magnetic resonance imaging
Cranial nerve

ABSTRACT

Objective: To investigate the potential influence of anatomical variation in the anterior inferior cerebellar artery (AICA) on the occurrence and severity of idiopathic sudden sensorineural hearing loss (ISSNHL).
Methods: Ninety ISSNHL patients were enrolled. The anatomical location of the AICA was exhibited using high-resolution magnetic resonance imaging (MRI), and the various AICA types classified by previously reported Chavda and Gorrie methods were analyzed. The severity of hearing loss in the ipsilateral ear among different AICA types was compared.
Results: Approximately 85.6% of subjects had unilateral ISSNHL (uISSNHL), and the others had bilateral ISSNHL (bISSNHL). In the uISSNHL group, the ratios of different AICA types were similar between the ipsilateral and contralateral ears. The ratios of the different AICA types in the bISSNHL group were similar to those in the uISSNHL group. In the uISSNHL group, pure tone audiometry (PTA) thresholds at 2 kHz, 4 kHz and 8 kHz of patients with Chavda type II AICA were higher than those of patients with Chavda type I and type III, with a significant difference at 4 kHz between type I and type II. There was a tendency of the PTA threshold in patients with Chavda type II or Gorrie type C to gradually increase from low to high frequency zones.
Conclusion: When the AICA enters the IAC (Chavda type II) or crosses between the 7th and 8th cranial nerves (Gorrie type C), the severity and frequency of hearing impairment in ISSNHL but not the occurrence of ISSNHL will be affected.

1. Introduction

Idiopathic sudden sensorineural hearing loss (ISSNHL) is a common disease encountered in otolaryngologic clinics (Chandrasekhar et al., 2019). Among the hypotheses regarding the pathophysiological mechanism of ISSNHL, the theory of blood supply disorder is favored by otologists (Kim et al., 2020; Kuhn et al., 2011). The inner ear is solely supplied by the labyrinthine artery, which mainly originates from the anterior inferior cerebellar artery (AICA) (Sunderland, 1945). However, the labyrinthine artery is too thin to be visualized by routine clinical examination (Sato and Kawagishi, 2014). Alternatively, visualizing AICA is achievable on clinical MRI, which may provide information on the suspected mechanism of blood supply disorder in ISSNHL.

The AICA originates from the vertebral-basilar artery and enters the cerebellopontine angle (CPA) posterolaterally with various appearances (Kim et al., 1990). The AICA may simply cross the entrance of the internal auditory canal (IAC) or enter it, forming a vascular loop (Kim et al., 1990). We speculate that entry of the AICA into the IAC to form a loop, which is more tortuous than that outside the IAC, renders individuals susceptible to developing ISSNHL due to compromised blood perfusion of the inner ear.

The relative position of the AICA to the surrounding cranial nerves also varies (Kim et al., 1990). In the CPA, the AICA may detach from or closely contact adjacent nerves. When the AICA courses between the 7th and 8th nerves, the blood supply to the

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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.
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https://doi.org/10.1016/j.joto.2023.07.001
1672-2930/

Abbreviations

AICA	anterior inferior cerebellar artery
bISSNHL:	bilateral idiopathic sudden sensorineural hearing loss
CPA	cerebellopontine angle
IAC	internal auditory canal
ISSNHL:	idiopathic sudden sensorineural hearing loss
NVC	neurovascular conflict
PTA	pure tone audiometry
SPACE	sampling perfection with application-optimized contrasts using a flip angle evolution
uISSNHL:	unilateral idiopathic sudden sensorineural hearing loss

inner ear may be compromised. We may further speculate that the close anatomical relationship of the AICA with the 7th and 8th cranial nerves may influence the occurrence and severity of ISSNHL by decreasing the blood supply to the inner ear.

There are controversial reports regarding the impact of anatomical variances of the AICA on the occurrence and outcome of ISSNHL (Chadha and Weiner, 2008; Ezerarslan et al., 2017; Kim et al., 2019). Both the spatial resolution of MRI and race may contribute to the various results. Aimed to investigate the potential contributions of AICA entry into the IAC and the close anatomical relationship between the AICA and adjacent nerves to ISSNHL, the current study was performed in Chinese patients using a high-resolution method of T2-sampling perfection with application-optimized contrasts using a flip angle evolution (SPACE) sequence in a 3 T MR system.

2. Methods

2.1. Subjects

This study was approved by the Ethics Committee of Changhai Hospital, Second Military Medical University, Shanghai, China (CHEC2020-107). All participants provided written informed consent. Patients diagnosed with ISSNHL by author JZ according to the Chinese guidelines (Editorial Board of Chinese Journal of Otorhinolaryngology et al., 2015) and hospitalized in Changhai Hospital were screened. The exclusion criteria were as follows: (1) conductive hearing loss, (2) ear malformations, (3) retro-cochlear lesions (internal auditory stenosis, acoustic neuroma, etc.), (4) recent acoustic trauma, (5) recent use of ototoxic drugs, (6) disease of the central nervous system (infarction, tumor, meningitis, multiple sclerosis, etc.), (7) hematopathy, (8) autoimmune diseases, (9) potential recent viral infection (fever, cough, herpes, and abnormal C-response protein), and (10) age younger than 18 years.

Ninety subjects were collected and divided into two groups: bilateral ISSNHL (bISSNHL) and unilateral ISSNHL (uISSNHL). Pure tone audiometry (PTA) (0.25, 0.5, 1, 2, 4, and 8 kHz) was performed to evaluate the subjects' hearing function. The history of chronic diseases (diabetes and hypertension) was recorded.

2.2. MRI protocol and image analysis

The inner ear and CPA were imaged using a 3T MR system (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) equipped with a 20-channel Tim 4G head/neck coil. The parameters for the SPACE sequence were the same as previously reported (Zou et al., 2019). Authors GZ, HL, ZZ and JZ jointly analyzed the images with the patient's information blinded. Author JZ has more than 22 years of experience in inner ear imaging.

To investigate whether entry of the AICA into the IAC has an influence on ISSNHL, the Chavda classification developed by McDermott was adopted: type I, the AICA is located within the CPA but outside the IAC; type II, the AICA forms a loop in the outer half of the IAC; and type III, the AICA loop reaches into the inner half of the IAC (McDermott et al., 2003) (Fig. 1).

To analyze the potential contribution of the close anatomical relationship between the AICA and the 7th and 8th cranial nerves to ISSNHL, the Gorrie classification was also adopted: type A, the AICA has no contact with adjacent nerves; type B, the AICA runs adjacent to the nerves; type C, the AICA courses between the 7th and 8th cranial nerves; and type D, the AICA physically displaces the eighth cranial nerve (Gorrie et al., 2010) (Fig. 1).

2.3. Statistical analysis

SPSS software (21.0, NY, USA) was used to analyze the data. The Mann–Whitney *U* test was used to compare the age differences. The chi-square test was used to compare the incidences of chronic diseases between the two ISSNHL groups and the proportions of the different AICA types between the ipsilateral ears and contralateral unaffected ears of the ISSNHL patients among different AICA types. The Kruskal–Wallis test and Mann–Whitney *U* test were used to compare the hearing threshold differences. The Bonferroni test was used for post hoc multiple comparisons. $P < 0.05$ was considered to indicate statistical significance.

3. Results

3.1. Subject profile (Table 1)

Seventy-seven ISSNHL subjects (85.6%) had uISSNHL, and the other 13 (14.4%) had bISSNHL. Among the bISSNHL subjects, 5 subjects (5.6%) had a synchronous bilateral onset, and the other 8 subjects (8.9%) had a metachronous bilateral onset. The average age of patients in the bISSNHL group was significantly older than that of patients in the uISSNHL group (67.0 vs. 47.6, $Z = -4.152$, $p < 0.001$). The bISSNHL group had a significantly higher incidence of diabetes than the uISSNHL group (38.5% vs. 10.4%, $\chi^2 = 7.092$, $p = 0.019$) and an insignificantly higher incidence of hypertension than the uISSNHL group (23.1% vs. 14.3%, $\chi^2 = 0.654$, $p = 0.419$).

3.2. PTA thresholds of ISSNHL patients

The frequency distribution of PTA thresholds (0.25, 0.5, 1, 2, 4, and 8 kHz) of ISSNHL patients is shown in Fig. 2. The average PTA thresholds at speech frequencies (0.5, 1, 2, and 4 kHz) of the ipsilateral ears of the uISSNHL patients and the bISSNHL patients were 79.4 ± 28.6 dB HL and 69.4 ± 30.4 dB HL, respectively. The differences in the PTA threshold of the ipsilateral ear at each tested frequency were statistically insignificant between the bISSNHL group and the uISSNHL group (Mann–Whitney *U* test, $p > 0.05$).

3.3. AICA locations and occurrence of ISSNHL

In the bISSNHL group, 30.8% of the diseased ears exhibited entry of the AICA into the IAC. In the uISSNHL group, the proportions were 42.9% and 45.5% on the ipsilateral and contralateral sides, respectively, and the difference was statistically insignificant ($\chi^2 = 0.105$, $p = 0.746$). The ratios of the three AICA types classified by the Chavda system are shown in Table 2. In general, type I is the most common, accounting for more than half of the cases, followed by type II, and type III is the least common. In the uISSNHL group,

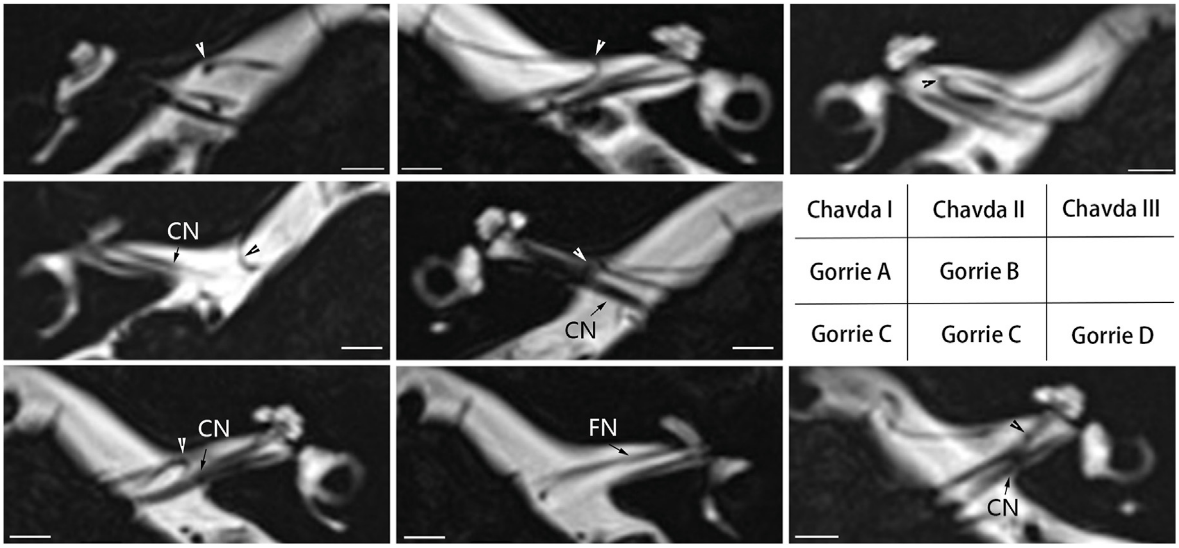

Fig. 1. Representative MRI demonstrating the Chavda and Gorrie classifications of the anterior inferior cerebellar artery (AICA). The distal point of the AICA is indicated with an arrowhead. CN: cochlear nerve; FN: facial nerve. Scale bars = 5 mm.

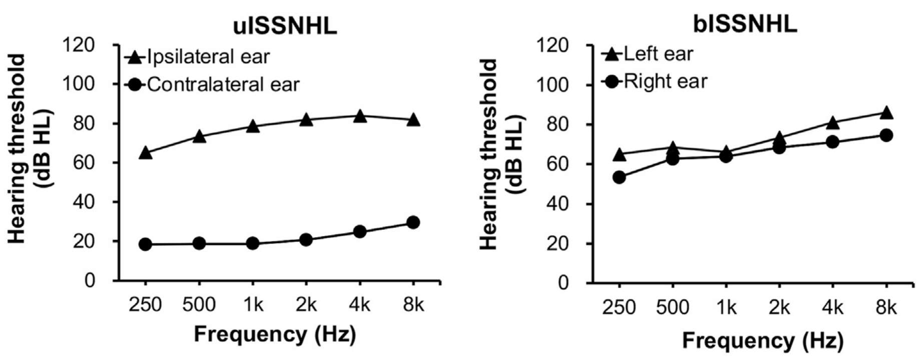

Fig. 2. Hearing thresholds of ISSNHL patients. bISSNHL: bilateral ISSNHL patient. uISSNHL: unilateral ISSNHL patient.

Table 1
Demographic data of the subjects.

	No.	Age	Gender (%)		Side (%)		Chronic disease (%)	
		(mean ± SD)	M	F	L	R	Diabetes	Hypertension
bISSNHL	13	67.0 ± 10.3	61.5	38.5	——		38.5	23.1
uISSNHL	77	47.6 ± 14.3	55.8	44.2	53.3	46.8	10.4	14.3
Total	90	50.4 ± 15.4	56.67	43.33	53.3	46.8	14.4	15.6

bISSNHL: the bilateral ISSNHL patient. uISSNHL: the unilateral ISSNHL patient. No.: number of patients.

Table 2
Chavda types of ISSNHL.

Subjects	No.	Chavda			Chi-square test	
		Type I N (%)	Type II N (%)	Type III N (%)	χ^2	*p*
bISSNHL	Diseased ear (26)	18 (69.2)	6 (23.1)	2 (7.7)	—	—
uISSNHL	Ipsilateral ear (77)	44 (57.1)	24 (31.2)	9 (11.7)	0.120	0.947
	Contralateral ear (77)	42 (54.5)	25 (32.5)	10 (13.0)		

bISSNHL: the bilateral ISSNHL patient. uISSNHL: the unilateral ISSNHL patient. No.: number of ears.

the differences in the ratios of the three Chavda types were statistically insignificant between the ipsilateral and contralateral sides ($p > 0.05$, Table 2). It can be inferred that the occurrence of ISSNHL is not affected by whether the AICA enters the IAC or by the depth of AICA entry.

Whether on the ipsilateral side or the contralateral side, the proportions of type A, type B, and type C classified by Gorrie were similar, while the proportion of Gorrie type D was very small (Table 3). In the uISSNHL group, the differences in ratios of the four Gorrie types between the ipsilateral and contralateral sides were statistically insignificant ($p > 0.05$, Table 3). Therefore, it can be considered that the anatomical relationship between the AICA and the 7th and 8th cranial nerves would not affect the occurrence of ISSNHL.

3.4. AICA locations and severity of ISSNHL

The correlations of PTA thresholds at 0.25, 0.5, 1, 2, 4, and 8 kHz in the ISSNHL ipsilateral ears with different AICA types were analyzed (Fig. 3). Regarding Chavda types, uISSNHL patients with Chavda type II AICA had more severe hearing loss at high frequencies than patients with type I or III AICA; in particular, the PTA threshold differences at 4 kHz between type II and type I were significant ($H = 7.194$, $df = 2$, $p = 0.046$). In the bISSNHL group, there were statistically insignificant differences in the PTA thresholds at each frequency among the three Chavda types ($p > 0.05$) (Fig. 3). For Gorrie types, in the uISSNHL group, there was a statistically insignificant difference in the PTA thresholds at each frequency among type A, type B, and type C (type D was not analyzed because there were too few cases) (Fig. 3). bISSNHL patients with type B or C had mildly higher PTA thresholds at most frequencies than those with type A, without significance.

We classified the tested frequencies into three zones: 250 Hz and 500 Hz as the low-frequency zone, 1 kHz and 2 kHz as the medium-frequency zone, and 4 kHz and 8 kHz as the high-frequency zone. The PTA thresholds of each zone represent the mean PTA thresholds of the defined two frequencies. A tendency of gradual increase from low to high frequency zones in the PTA thresholds of patients with Chavda type II or Gorrie type C AICA was observed. The PTA threshold in the high-frequency zone was significantly higher than that in the low-frequency zone in uISSNHL patients with Chavda type II AICA ($H = 9.419$, $df = 2$, $p = 0.009$) (Fig. 4).

Table 3
Gorrie types of ISSNHL.

Subjects	No.	Gorrie				Chi-square test	
		Type A N (%)	Type B N (%)	Type C N (%)	Type D N (%)	χ^2	*p*
bISSNHL	Diseased ear (26)	7 (26.9)	11 (42.3)	8 (30.8)	0 (0)	—	—
uISSNHL	Ipsilateral ear (77)	21 (27.3)	25 (32.5)	28 (36.4)	3 (3.9)	2.905	0.428
	Contralateral ear (77)	15 (19.5)	33 (42.9)	24 (31.2)	5 (6.5)		

bISSNHL: the bilateral ISSNHL patient. uISSNHL: the unilateral ISSNHL patient. No.: number of ears.

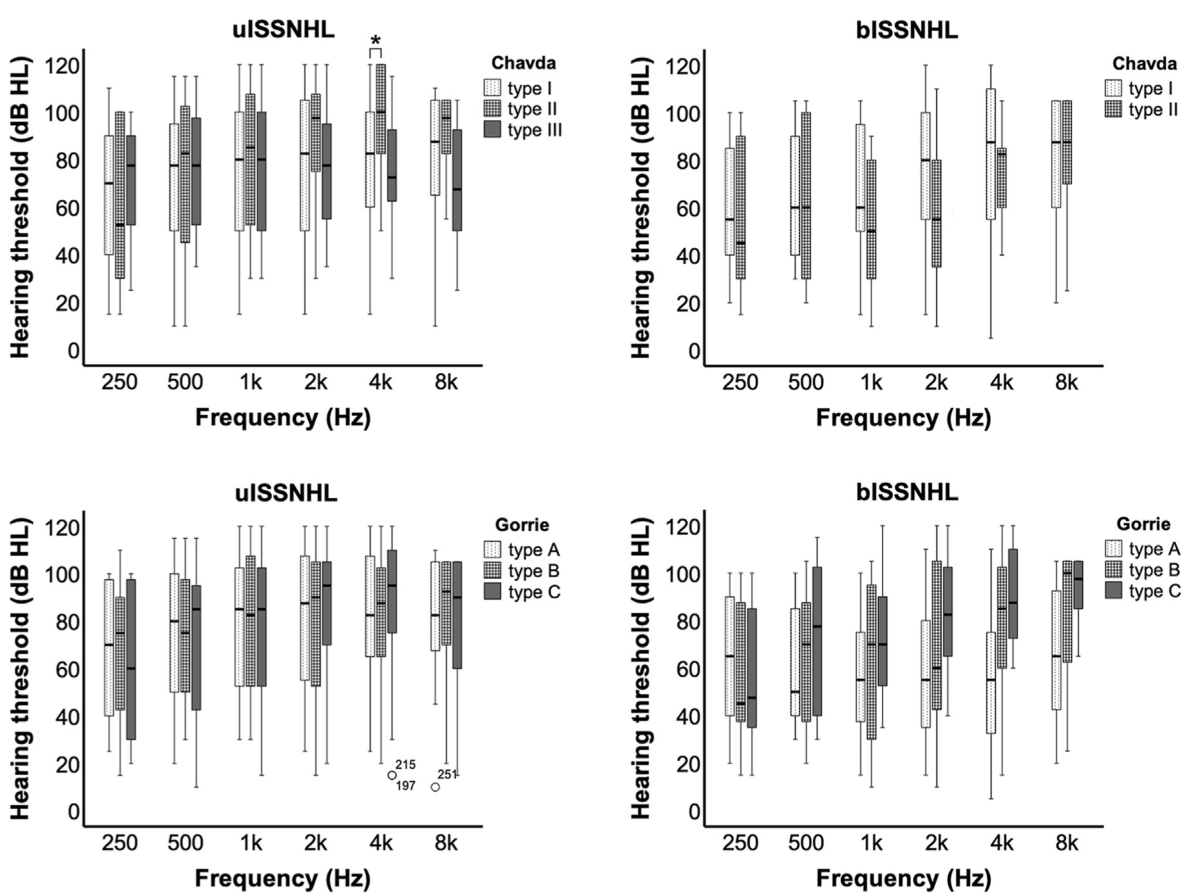

Fig. 3. Hearing thresholds of ISSNHL patients with different Chavda types and Gorrie types. *indicates $p < 0.05$. bISSNHL: bilateral ISSNHL patient. uISSNHL: unilateral ISSNHL patient. The bar for Chavda type III in bISSNHL is not shown because there were only 2 ears with this type.

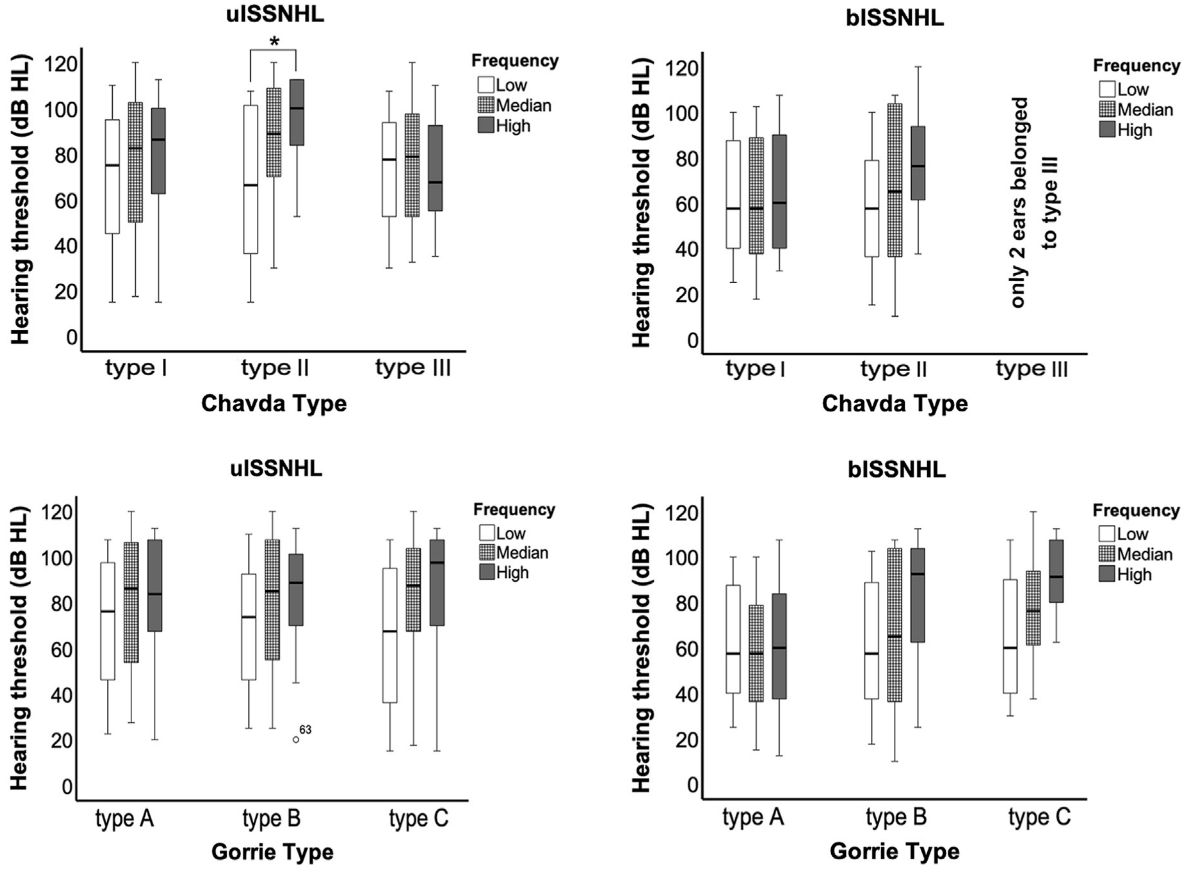

Fig. 4. Pure tone audiometry thresholds at low, medium and high frequency zones in ISSNHL patients with different Chavda types and Gorrie types. *indicates $p < 0.05$. bISSNHL: bilateral ISSNHL patient. uISSNHL: unilateral ISSNHL patient.

4. Discussion

The present study showed that more than 85% of ISSNHL patients had a unilateral onset, and 5.6% of patients had a synchronous bilateral onset, with the latter proportion being slightly higher than that of previous reports (Byl, 1984; Kuhn et al., 2011). We found that bISSNHL patients were older and had higher incidences of metabolic disorders (diabetes or hypertension) than uISSNHL patients. This suggests that advanced age and metabolic disorders contribute to the occurrence of bilateral ISSNHL.

Both Sunderland and Mazzoni reported that approximately 40% of human temporal bones exhibit an AICA lying inside the IAC as a common phenomenon in the population (Mazzoni, 1969; Sunderland, 1945). Similarly, we found that 45.5% of contralateral unaffected ears of the unilateral ISSNHL patients had the AICA entering the IAC. Kim et al. reported that the AICA entered the IAC in 49.0% of ipsilateral ears of unilateral ISSNHL patients, which was nonsignificantly different from that of the contralateral asymptomatic ear (Kim et al., 2019). In the present study, a statistically insignificant difference in the ratio of AICA entry into the IAC between the two ears of ISSNHL patients was detected. There were reports that the presence of the AICA in the IAC was more prominent among symptomatic ears than among contralateral asymptomatic ears. McDermott et al. reported that an AICA loop in the IAC was significantly associated with sensorineural hearing loss but that hearing loss was not particularly associated with ISSNHL (McDermott et al., 2003). Ezerarslan et al. reported that the AICA entered the IAC in 35.3% of ipsilateral ears and 15.8% of contralateral asymptomatic ears in unilateral SSNHL, which was a significant difference (Ezerarslan et al., 2017). However, the ratio of AICA entry into the IAC in the contralateral ears in Ezerarslan's study was obviously smaller than that in the cadaver study (Mazzoni, 1969; Sunderland, 1945) and the present study. Therefore, the significant difference between ipsilateral ears and contralateral ears in Ezerarslan's study is doubtable. These results indicate that AICA entry into the IAC is a common anatomical phenomenon, and this anatomical variation does not increase the incidence of SSNHL.

Why did uISSNHL patients with Chavda type II AICA have greater hearing loss? Acute vestibulocochlear dysfunction characterized by sensorineural hearing loss and vertigo has been recognized as an important manifestation of AICA infarction that is often accompanied by other brainstem or cerebellar signs (such as facial paralysis, ataxia and infarction found in MRI) (Lee, 2012). AICA hypoperfusion without infarction can also induce sensorineural hearing loss and vertigo (Kim et al., 2022). Reduced recovery of ISSNHL patients exhibiting AICA entry into the IAC has previously been reported (Ezerarslan et al., 2017; Kim et al., 2019). In type II, the AICA forms a loop in the outer half of the IAC. This tortuous path in the narrow IAC may influence the blood flow of the AICA and cause a reduction in blood supply to the inner ear, especially in the case of long-term exposure to hyperglycemia and hypertension. According to this idea, the Chavda type III AICA enters the IAC more deeply than the type II AICA does, which is more likely to affect the blood supply to the inner ear. However, in the present study, we did not find that ISSNHL patients with Chavda type III AICA had more serious hearing loss, which may have been due to the insufficient number of patients with type III.

Ouaknine found that 36% of the AICAs passed between the 7th and 8th cranial nerves (Ouaknine, 1982). In the present study, we found that 30.8%-36.4% of ipsilateral ears of ISSNHL patients had a Gorrie type C AICA. The anatomical relationship between the AICA and the 7th and 8th cranial nerves also had some influence on ISSNHL. Gorrie et al. demonstrated a statistically significant association between the presence of a type C AICA and hearing loss (Gorrie et al., 2010). We found that bISSNHL patients with Gorrie type C or B AICAs had more severe hearing loss than patients with Gorrie type A AICA, and the PTA thresholds of ISSNHL patients with Gorrie type C AICA showed a gradual increase from low to high frequency zones. Nerve dysfunction caused by vascular compression, also called neurovascular conflict (NVC), has been widely accepted as the mechanism of hemifacial spasm, trigeminal neuralgia, vestibular paroxysmia, and pulsatile tinnitus (Applebaum and Valvassori, 1984; Jannetta, 1975; Wilkins, 1985). These problems are mostly hyperfunctional, not hypofunctional as is hearing loss. Ungar et al. reported that auditory neural function was not impaired by the contacted AICA (Ungar et al., 2018). Tzahi Yamin also found that NVC of the 8th cranial nerve was not the cause of ISSNHL (Yamin et al., 2023). Therefore, we believe that the hearing loss in ISSNHL patients with Gorrie type C AICAs was not associated with AICA compression-induced auditory nerve dysfunction. From another perspective, the AICA is compressed by the 7th and 8th cranial nerves when they are in close contact, especially when the AICA travels between the 7th and 8th cranial nerves. Kim reported that AICA hypoperfusion without infarction can induce sensorineural hearing loss and vertigo (Kim et al., 2022). The compressed AICA may cause insufficient blood supply to the inner ear, which plays a role in the severity of hearing loss in ISSNHL patients with Gorrie type C AICAs.

There are obvious limitations of the present study: it has been reported that metabolic disorders (hypertension, diabetes and lipid disorders) contribute to cardiac and/or cerebral vascular events(Alloubani et al., 2021; Flora and Nayak, 2019); therefore, hypertension and diabetes may aggravate the influence of anatomical variations in the AICA on ISSNHL. A large sample study should be performed in the future to compare the differences between ISSNHL patients with and without metabolic disorders. All the subjects were hospitalized patients, most of whom had severe hearing loss. The patients with mild hearing loss or whose hearing recovered after routine treatment did not receive MRI examinations. This may have influenced the results.

5. Conclusion

Anatomical variation in the AICA does not influence the occurrence of ISSNHL but may have a role in the severity and frequency of hearing loss in individuals with ISSNHL.

Funding

This work was supported by the National Natural Science Foundation of China [81771006].

Declarations of competing interest

All authors declare that they have no conflicts of interest.

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