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The Relationship Between Cochlear Nerve and Cochlear Nerve Canal Dimensions in Incomplete Partition Types

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ABSTRACT

Introduction: Incomplete partition (IP) type and accompanying cochlear nerve (CN) anomalies affect the patient's management. We revealed the cochlear nerve area (CNA), cochlear nerve canal width (CNCW), and inner auditory canal width (IACW) of IP types.

Methods: We retrospectively scanned patients with IP. There were 88 IP ears (26 IP type 1, 54 IP type 2, 8 IP type 3) and 54 controls. The CNCW and IACW were measured in axial temporal computed tomography sections. The CNA and facial nerve area (FNA) were measured in the distal IAC on the sagittal-oblique plane of 3D constructive interference steady-state T2-weighted magnetic resonance images.

Results: CNA and CNA/FNA values for each IP type differed significantly compared with the control group. However, the CNCW and IACW values did not differ significantly. The CNA was the least in IP 1 cases. Five CN aplasia were detected, and all were associated with IP type 1 anomaly (3.5% of all, 5.6% of IP types, and 19.2% of IP type 1 cases). CN hypoplasia was observed in 10 IP type 1 (38.5% of IP 1), 6 IP type 2 (6.8% of IP type 2), and 1 IP type 3 (12.5% of IP type 3) ears. None of the CN hypoplasia had a CNC hypoplasia.

Conclusion: CN aplasia and hypoplasia most frequently accompanied with IP type 1 in our study. Therefore, they need an extra interest in CN evaluation. CNCW and IACW are not very useful in predicting CN dysplasia in IP cases.

Keywords: Incomplete partition, cochlear nerve, cochlear nerve canal width, inner auditory canal width

Introduction

One-fourth of sensorineural hearing loss (SNHL) cases have an anomaly that computed tomography (CT) or magnetic resonance imaging (MRI) can detect, and the detection rate with CT (25%) was higher than with MR (18%) (p=0.0001) (1,2). While the most common anomalies detected by CT were cochlear or semicircular canal anomalies, the most common anomalies detected by MRI were cochlear nerve (CN) abnormalities and semicircular canal anomalies (2). Incomplete partition (IP) disorders describe the cochlea anomalies that comprise approximately 40% of the inner ear anomalies and are divided into three groups. Types of IP are distinguished by the presence or absence of the cochlea's partition to varying degrees (3). Some patients with IP may not have a chance for a cochlear implant (CI) due to the possibility of CN aplasia (1). Patients with normal CNs had better post-CI outcomes rather than patients with CN dysplasia. Patients with a narrower bony cochlear nerve canal (CNC) showed less favorable results, even if the CN was intact (4).

The CNC, also called the cochlear aperture, is the central bony passage at the base of the modiolus that allows the course of the CN from the Cochlea to the internal acoustic canal (IAC). When the CNC is not visible, it is considered aplasia; when the cochlear nerve canal width (CNCW) is narrow, it is regarded as hypoplasia (5). In a study in SNHL cases with normal cochlea and CN abnormalities, the CNC diameter was smaller than 1.5 mm in 90.6% of patients with CN aplasia and 31.7% of patients with CN hypoplasia (6). Narrowing of the IAC maybe seen with CNC abnormalities. Different cut-off values have been used for the inner auditory canal's width (IACW) in different studies (7-9). The CN should be evaluated in narrow IAC, CNC hypoplasia, or CNC aplasia. While CN hypoplasia or aplasia might be expected to attend CNC hypoplasia, both can also be seen with a normal CNC.

However, CNC aplasia accompanies CN aplasia (10,11). It is considered hypoplastic if the diameter of the CN is smaller than the normal CN on the contralateral side or the normal facial nerve (FN) on the same side (12). Evaluation of the CNC and IACW is possible with high-resolution CT of the temporal bone. However, thin-section T2-weighted MR sequences should be used for CN evaluation (13).

In the literature, numerous studies have evaluated the relationship between CNCW and CN hypoplasia-aplasia. However, these studies assessed independently of the normal-abnormal configuration of the

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cochlea (5,10,12). It is essential to reveal the form of the CN (aplasia, hypoplasia, or normal) for planning the management approach. The relationship between cochlear nerve area (CNA) and CNCW in IP types have not yet been studied yet. This study revealed the CNA, CNCW, and IACW and their relationship with CN dysplasia in IP patients.

Methods

This study was conducted at our hospital in accordance with the principles of the Declaration of Helsinki Ethics Committee Approval was taken from University of Health Sciences Turkey, İstanbul Training and Research Hospital Clinical Research Ethics Committee (approval number: 326, date: 27.10.2022).

Subjects

For this study, we retrospectively scanned our hospital's Picture Archive Communication System for patients diagnosed with IP based on the classification of Sennaroğlu and Bajin (1) from January 2017 to October 2022 from January 2017 to January 2022. We reached 97 ears diagnosed with IP who underwent temporal CT and MRI. Seven ears were excluded because they had CT or MR images unsuitable for measurement, previous skull base or temporal surgery, skull base or facial trauma with fracture, history of head and neck malignancy, and calvaria abnormalities or deformities. Of the remaining 88 ears, 26 had IP type 1, 54 had IP type 2, and 8 had IP type 3. In the same period, 54 patients under 18 with CT and MRI scans for mastoiditis and cholesteatoma, who had no inner ear anomalies, were randomly selected for the control group.

Imaging and Analysis

All CT and MRIs of the SNHL and control patients were performed in our radiology department for routine medical treatment. The CT images were performed with a 64-slice CT (MSCT; Brilliance 64, Philips Medical System, Best, the Netherlands). All the scans were obtained as routine HRCT of temporal bone imaging in the supine position with the scanning baseline parallel to the orbitomeatal line (kVp=120, mAs=100, FOV=240 mm, slice thickness=0.5 mm). The MR images were performed with a 1.5-T scanner (Siemens Healthcare, Aera Magnetom, Erlangen, Germany) equipped with an 8-channel head coil. The imaging protocol included axial 3D constructive interference steady-state (CISS) T2 (TR/TE: 5.39/2.40 ms, matrix: 384x211, NSA: 1, slice thickness: 0.72 mm) images as a part of the standard protocol for temporal MRI at our institution.

Each cochlea's CT and MRI scan were transferred to the Syngo Via® workstation (Siemens Medical Solutions) for precise measurements. All images were examined separately by a radiologist experienced in temporal bone imaging. The CNCW was measured on axial CT images at the mid-modiolar plan (Figure 1A). The IACW was measured at the mid-point in axial CT sections (Figure 1B). Sagittal-oblique images of 3D CISS T2-weighted MRI were performed perpendicular to the nerve's long axis by multiplanar reconstructions. The cochlear and FN cross-sectional areas were measured separately in the distal IAC on the sagittal-oblique plane of the CISS images (Figure 2). The CN was defined as aplasia if the CN could not be seen in any reconstructed image, and the area was recorded as 0 mm^2 (Figure 3A). The ratio was calculated by dividing the ipsilateral CN by the facial nerve areas (CNA/FNA) (14). CN is considered hypoplastic if the area of the CN is smaller than the normal CN on the contralateral side or the normal FN on the same side (Figure 3B) (12). In cases where the CNC measurement was not made because the canal opening was not chosen, the CNC was noted as atretic and recorded as 0 mm. It was defined as stenotic when the CNCW was <1.5 mm (6). We evaluated the incidence of CN aplasia and hypoplasia in each case group when we separated the CNC width as aplasia, stenotic, and normal (6). If the IACW was below 4 mm, it was considered abnormal, and its relationship with CN hypoplasia and aplasia was evaluated (15).

Statistical Analysis

In the descriptive statistics of the data, mean, standard deviation, median, minimum, maximum, frequency, and ratio values were used.

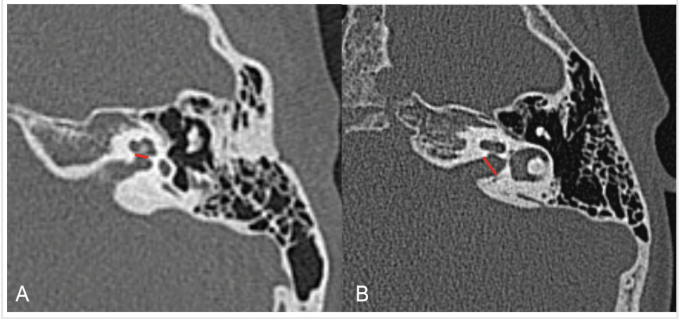

Figure 1. (A) CNCW measurement at the mid-modiolar plan on axial CT images. (B) IACW measurement at the mid-point in axial CT sections

CNCW: Cochlear nerve canal width, CT: Computed tomography, IACW: Inner auditory canal width

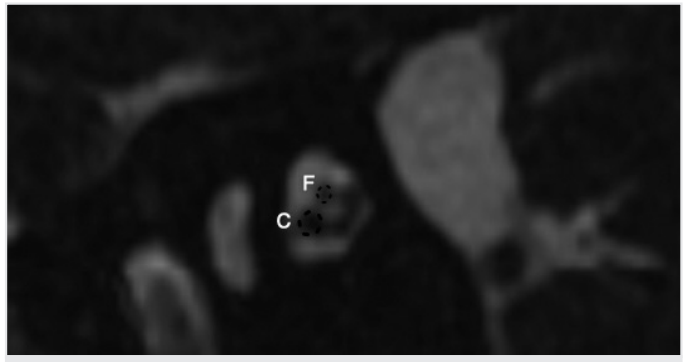

Figure 2. Cochlear and facial nerve cross-sectional area measurement

F: Facial nerve, C: Cochlear nerve

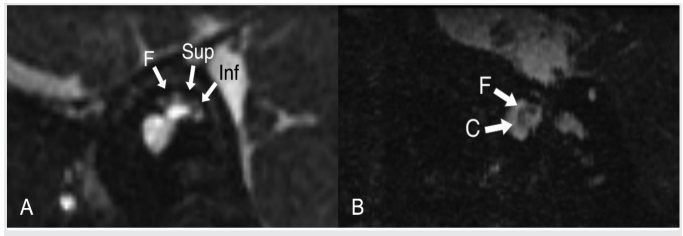

Figure 3. 3D CISS T2-weighted MRI images of (A) cochlear aplasia and (B) cochlear hypoplasia

CISS: Constructive interference steady-state, MRI: Magnetic resonance imaging, F: Facial nerve; C: Cochlear nerve; inf: Inferior colliculus Sup: Superior colliculus

The distribution of variables was measured using the Kolmogorov-Smirnov test. Kruskal-Wallis, Mann-Whitney U test was used to analyse independent quantitative data. The Wilcoxon test was used in the analysis of dependent quantitative data. SPSS 28.0 program was used in the analysis.

Results

The mean age of the cases included in the study was 61.4±46.6 months in control, 46.2±55.4 months in IP type 1, 67.5±53.2 months in IP type 2, and 163.3±57.6 months in IP type 3. The mean values of CNA, FNA, and CNA/FNA for each group are summarized in Table 1.

Both CNA and CNA/FNA values for each IP type differed significantly compared with the Control group (Table 1, Figure 4).

Additionally, no significant difference was found between all groups for FNA. CNCW and IACW values are also summarized in Table 1 for each group. Both did not differ significantly between the control and IP types.

CN dysplasia was not detected in any case in the control group. In our case group, five CN aplasia was detected, and all were associated with IP type 1 anomaly (3.5% of all, 5.6% of IP type, and 19.2% of IP type 1 cases). CNC stenosis was found in 4 patients with CN aplasia, and CNC hypoplasia was found in 1 patient. CN hypoplasia was seen in 10 IP type 1 (38.5% of IP 1), 6 IP type 2 (6.8% of IP type 2), and 1 IP type 3 (12.5% of IP type 3) ears. None of these ears with CN hypoplasia had a CNC hypoplasia.

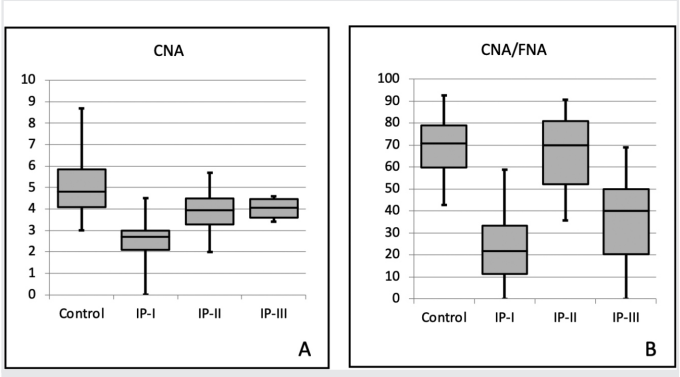

Figure 4. Box plot of the mean values for CNA and CNA/FNA
CNA: Cranial nerve area, FNA: Facial nerve area

The CNC was hypoplastic in 2 ears of the control group and one ear of the IP type 1, and the CN diameter was within the normal limits in these cases.

There is no significant difference in IACW between the control and the IP types. IACW was measured below 4 mm in 4 cases in the control group, 4 cases in the IP type 1 group, and 6 cases in the IP type 2 group. CN diameter in all these control and IP type 2 cases was within normal limits. In 4 cases with IP type 1 and IACW were measured below 4 mm; two have CN aplasia, one has CN hypoplasia, and the other has normal CN diameter. The IAC diameter was greater than 4 mm in all IP type 3 cases.

Discussion

The CN condition affects the CI results in IP and other SNHL cases (1). Therefore, in this study, we revealed whether the CN dimensions of IP cases differ from those of normal subjects and which IP types are more accompanied by CN dysplasia. We also investigated whether CNC and IAC widths may be associated with CN dysplasia and whether they differ from normal cases. The mean CNA value was 5±1.2 mm in the control group compared to the IP types, and there was a statistically significant difference. The lowest CNA was found in IP type 1 cases than in the other IP types and the control in our results. We did not find a significant difference in FNA between the IP types and the control. Naguib et al. (14) also found no significant difference in the FNA between patients with SNHL patients and control. They stated that the FN could be used as a reference in evaluating CN dimensions (14). Therefore, FNs can be used as a reference in IP cases too. CNA/FNA values differ between control and IP types, similar to CNA values in our results.

Carner et al. (16), in their study on 36 patients with CN aplasia, found that IP type 1 anomaly was accompanied in 5 cases and IP type 2 anomaly in 4 cases. In the study of Sorge et al. (17) found middle and inner ear anomalies in 10 of 32 cases with CN defects. Among these, IP type 2 was accompanied in 3 ears, and IP type 1 was in two ears (17). Tahir et al. (18) found 3 IP type 1 cases in 41 patients with CN aplasia.

Table 1. Statistical analysis of MRI and CT measurements

		Control	IP-1	IP-2	IP-3
CNA	Mean ± SD	5.0±1.2	2.3±1.3	3.9±0.8	4.0±0.4
	p		**0.001**	**0.001**	**0.029**
FNA	Mean ± SD	3.2±0.9	3.1±0.7	3.1±0.6	3.3±0.5
	p		0.750	0.963	0.388
CNA/FNA	Mean ± SD	1.6±0.3	0.8±0.5	1.3±0.3	1.3±0.2
	p		**0.001**	**0.001**	**0.002**
CNCW	Mean ± SD	2.2±0.4	2.0±1.0	2.1±0.3	2.2±0.4
	p		0.930	0.691	0.817
IACW	Mean ± SD	5.2±1.0	4.8±0.9	5.3±1.1	5.4±1.1
	p		0.058	0.866	0.674

Statistically significant data with p<0.05 are bolded. MRI: Magnetic resonance imaging, CT: Computed tomography, CNA: Cochlear nerve area, FNA: Facial nerve area, CNCW: Cochlear nerve canal width, IACW: Inner auditory canal width, SD: Standard deviation

CN aplasia was detected in only five cases among our entire patient and control group, and all of them were associated with IP type 1 anomaly. Suk et al. (19), in their study evaluating the surgical results in IP type 1 cases, found hypoplasia in 9 (53%) of 17 cases in which the CN was assessed. In an MRI examination of the IP type 1 cases, hypoplasia of the CN was found in 16.2% and aplasia of the CN in 6.3% (20). In our study, we examined 26 IP type 1 cases, and 38.5% (n=10) of them had CN hypoplasia, and 19.2% (n=5) had CN aplasia. CN hypoplasia was also seen in 6 IP type 2 (6.8% of IP type 2) and 1 IP type 3 (12.5% of IP type 3) ears. None of these ears with CN hypoplasia had a CNC stenosis.

It is an expected finding that the CNC is narrower in patients with SNHL than in patients with normal hearing (5,11). However, our results found no significant difference between the CNCW in the normal cases and IP types (Table 1). The addition of CNC stenosis to the inner ear abnormalities may accompany more severe SNHL (5). Zainol Abidin et al. (21) reported in their research that the most common cochlear anomaly accompanying CNC stenosis was IP type 2 (23%). However, 37 of the 48 cochlear anomalies in their study were IP type 2 cases. Of 38 patients with a stenotic CNC in a study, 6 had IP type 1, and 1 had IP type 2 (18). The CNCW was measured below 1.5 mm in just three ears in our study. Two of these CNC stenoses were in the control group, and one was in the IP type 1. There were no significant Accompaniment of CNC stenosis to IP cases. Stenosis of the CNC often accompanies CN hypoplasia or aplasia, and the severity of hearing loss and canal narrowing has been associated with each other (5; 11). However, concomitant CN dysplasia was not found in all three of our cases with CNC stenosis.

Because of the high incidence of CN abnormalities, IAC stenosis has been considered a Contraindication for CI application in previous studies (22). Although CN evaluation with MRI is routinely performed today, narrow IAC retains its ability to predict low CI success because it indicates CN abnormalities. In addition, in cases where CNC dimensions are within normal limits, CN dysplasia may not be predicted without MRI (10). In a study conducted in cases with normal cochlear configuration, IAC diameter was less than 3 mm in 50% of cases with CN aplasia and 40% with CN hypoplasia (6). Giesemann et al. (23) found that 92% of 25 cases with IAC malformation were present with VCN aplasia in their study on a case group with different inner ear anomalies. Glastonbury CM accepted 4 mm as the limit for IAC abnormality evaluated on 3D T2W MR images and showed that IAC abnormality was accompanied in 16 of 18 ears with CN abnormality (15). Monsanto et al. (24) evaluated 38 temporal bone specimens inner ear anomalies in their study. The vestibulocochlear nerve, CNC, and IAC were markedly hypoplastic in a single IP type 1 case. IAC and CNC were normal in the two IP type 2 cases, but nerve fibers were significantly lost (24). In a study evaluating the IAC width (at the level of porus acusticus internus), there were 8 cases of IP type 1, 16 cases of IP type 2, and 8 cases of IP type 3. The IAC width was approximately 5.5 mm in the control group, and there was no significant difference between the IP types and the control group (25). We found a mean IACW of 5.2±1.0 mm in the control group and did not find a significant difference with IP types. IACW was measured below 4 mm in 4 cases in the control group, 4 cases in the IP type 1 group, and 6 cases in the IP type 2 group. IAC diameter was greater than 4 mm in all IP type 3 cases. CN diameter in all these control and IP type 2 cases was within normal limits. In 4 cases with IP type 1 and IACMW were measured below 4 m; two have CN aplasia, one has CN hypoplasia, and the other has a normal CN diameter.

Study Limitations

The limitations arising from the study's retrospective nature, with the fact that the patient population excludes other inner ear anomalies, causes us to be unable to make a comprehensive comparison. A single author made measurements, and inter-observer variability was not checked. All measurements were made manually. Difficulties and differences may arise from the complex anatomical structure. Especially, in anatomical variations and advanced abnormalities, measuring and standardizing measurements becomes difficult. MRI may not provide sufficient resolution to detect nerve thickness in cases with extremely thin nerve fibers.

Conclusion

Because IP type and accompanying CN anomalies may affect post-implantation performance, their preoperative determination will affect the patient's management. CNA was the highest in the control group and least in IP type 1 cases. There was a significant difference between control and IP types in CNA and CNA/FNA. Therefore, the CN status of IP cases should be carefully evaluated. CN dysplasia was the most frequently accompanying the IP type 1 cases (CN hypoplasia 38.5%, CN aplasia 19.2%) among the IP types, so they need an extra interest in CN evaluation. There was no significant difference in CNCW and IACW between the control and IP cases. It could not be said that CNC and IAC widths are very useful in predicting CN dysplasia in IP cases.

Ethics Committee Approval: This study was conducted at our hospital in accordance with the principles of the Declaration of Helsinki Ethics Committee Approval was taken from University of Health Sciences Turkey, İstanbul Training and Research Hospital Clinical Research Ethics Committee (approval number: 326, date: 27.10.2022).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Surgical and Medical Practices - D.Ö.A.; Concept - D.Ö.A., Y.K., A.S.M.; Design - D.Ö.A., K.F.K., M.B.U.; Data Collection or Processing - D.Ö.A., K.F.K.; Analysis or Interpretation - D.Ö.A., Y.K.; Literature Search - D.Ö.A., M.B.U.; Writing - D.Ö.A.

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References

1. Sennaroğlu L, Bajin MD. Classification and Current Management of Inner Ear Malformations. Balkan Med J 2017; 34: 397-411.
2. Zhang J, Sawaf T, Anne S, Pham GN, Pakanati K, Raol N, et al. Imaging in pediatric bilateral sensorineural hearing loss: Diagnostic yield with computed tomography versus magnetic resonance imaging. Int J Pediatr Otorhinolaryngol 2021; 147: 110778.

3. Kontorinis G, Goetz F, Giourgas A, Lenarz T, Lanfermann H, Giesemann AM. Radiological diagnosis of incomplete partition type I versus type II: significance for cochlear implantation. Eur Radiol 2012; 22: 525-32.

4. Chung J, Jang JH, Chang SO, Song JJ, Cho SW, Kim SY, et al. Does the Width of the Bony Cochlear Nerve Canal Predict the Outcomes of Cochlear Implantation? Biomed Res Int 2018; 2018: 5675848.

5. Wilkins A, Prabhu SP, Huang L, Ogando PB, Kenna MA. Frequent association of cochlear nerve canal stenosis with pediatric sensorineural hearing loss. Arch Otolaryngol Head Neck Surg 2012; 138: 383-8.

6. Yan F, Li J, Xian J, Wang Z, Mo L. The cochlear nerve canal and internal auditory canal in children with normal cochlea but cochlear nerve deficiency. Acta Radiol 2013; 54: 292-8.

7. El Sadik AO, Shaaban MH. The relationship between the dimensions of the internal auditory canal and the anomalies of the vestibulocochlear nerve. Folia Morphol (Warsz) 2017; 76: 178-85.

8. McClay JE, Tandy R, Grundfast K, Choi S, Vezina G, Zalzal G, et al. Major and minor temporal bone abnormalities in children with and without congenital sensorineural hearing loss. Arch Otolaryngol Head Neck Surg 2002; 128: 664-71.

9. Chetcuti K, Kumbla S. The internal acoustic canal--another review area in paediatric sensorineural hearing loss. Pediatr Radiol 2016; 46: 562-9.

10. Adunka OF, Jewells V, Buchman CA. Value of computed tomography in the evaluation of children with cochlear nerve deficiency. Otol Neurotol 2007; 28: 597-604.

11. Miyasaka M, Nosaka S, Morimoto N, Taiji H, Masaki H. CT and MR imaging for pediatric cochlear implantation: emphasis on the relationship between the cochlear nerve canal and the cochlear nerve. Pediatr Radiol 2010; 40: 1509-16.

12. Casselman JW, Offeciers FE, Govaerts PJ, Kuhweide R, Geldof H, Somers T, et al. Aplasia and hypoplasia of the vestibulocochlear nerve: diagnosis with MR imaging. Radiology 1997; 202: 773-81.

13. Young JY, Ryan ME, Young NM. Preoperative imaging of sensorineural hearing loss in pediatric candidates for cochlear implantation. Radiographics 2014; 34: E133-49.

14. Naguib NNN, Hey C, Shaaban MS, Elabd AM, Hassan HHM, Gruber-Rouh T, et al. Assessment of the cochlear nerve to facial nerve size ratio using MR multiplanar reconstruction of the internal auditory canal in patients presenting with acquired long-standing hearing loss. Br J Radiol 2017; 90: 20160870.

15. Glastonbury CM, Davidson HC, Harnsberger HR, Butler J, Kertesz TR, Shelton C. Imaging findings of cochlear nerve deficiency. AJNR Am J Neuroradiol 2002; 23: 635-43.

16. Carner M, Colletti L, Shannon R, Cerini R, Barillari M, Mucelli RP, et al. Imaging in 28 children with cochlear nerve aplasia. Acta Otolaryngol 2009; 129: 458-61.

17. Sorge M, Sorge I, Pirlich M, Fuchs M, Meuret S, Hirsch FW, et al. Diameter of the Cochlear Nerve Canal predicts Cochlear Nerve Deficiency in Children with Sensorineural Hearing Loss. Rofo 2022; 194: 1132-9.

18. Tahir E, Bajin MD, Atay G, Mocan BÖ, Sennaroğlu L. Bony cochlear nerve canal and internal auditory canal measures predict cochlear nerve status. J Laryngol Otol 2017; 131: 676-83.

19. Suk Y, Lee JH, Lee KS. Surgical outcomes after cochlear implantation in children with incomplete partition type I: comparison with deaf children with a normal inner ear structure. Otol Neurotol 2015; 36: e11-7.

20. Parlak S, Akgoz Karaosmanoglu A, Arslan S, Sennaroglu L. Incomplete Partition type I: Radiological Evaluation of the Temporal Bone. Acta Medica 2021; 52: 332-40.

21. Zainol Abidin Z, Mohd Zaki F, Kew TY, Goh BS, Abdullah A. Cochlear nerve canal stenosis and associated semicircular canal abnormalities in paediatric sensorineural hearing loss: a single centre study. J Laryngol Otol 2020; 134: 603-9.

22. Shelton C, Luxford WM, Tonokawa LL, Lo WW, House WF. The narrow internal auditory canal in children: a contraindication to cochlear implants. Otolaryngol Head Neck Surg 1989; 100: 227-31.

23. Giesemann AM, Kontorinis G, Jan Z, Lenarz T, Lanfermann H, Goetz F. The vestibulocochlear nerve: aplasia and hypoplasia in combination with inner ear malformations. Eur Radiol 2012; 22: 519-24.

24. Monsanto RDC, Sennaroglu L, Uchiyama M, Sancak IG, Paparella MM, Cureoglu S. Histopathology of Inner Ear Malformations: Potential Pitfalls for Cochlear Implantation. Otol Neurotol 2019; 40: e839-46.

25. Bächinger D, Breitsprecher TM, Pscheidl A, Dhanasingh A, Mlynski R, Dazert S, et al. Internal auditory canal volume in normal and malformed inner ears. Eur Arch Otorhinolaryngol 2023; 280: 2149-54.