The Importance of Radiological Measurements at Determination and Classification of Inner Ear Anomalies

İç Kulak Anomalilerinin Saptanması ve Sınıflandırılmasında Radyolojik Ölçüm Tekniğinin Önemi

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ÖZET

GİRİŞ ve AMAÇ: Sensori-nöral işitme kaybı (SNİK) olan hastalarda şiddetli iç kulak malformasyonlarının saptanma oranı, yüksek çözünürlüklü temporal kemik bilgisayarlı tomografisi (TKBT) vizüel değerlendirmesine ayrıntılı ölçüm teknikleri eklenmesi ile arttırılabilir.

YÖNTEM ve GEREÇLER: Çalışmaya 2008-2010 yılları arasında TKBT çekilen 48 hasta dahil edilmiştir. Bunların 24'ü SNİK dışı otolojik problemler ile başvurmuşken diğerlerinde konjenital SNİK bulunmaktadır. 4 sıralı multidedektör BT ile 1,2 mm kesit kalınlığında aksiyel görüntüler alınmıştır. Rekonstrükte edilen koronal görüntüler 0,6 mm kesit kalınlığında oluşturulmuştur. Tüm iç kulak yapılarının sayısal ölçümleri ve vizüel değerlendirmeleri yapılarak SNİK bulunan ve bulunmayan gruplar arasında karşılaştırılmıştır.

BULGULAR: SNİK bulunan hastalarda TKBT' nin sadece vizüel yöntemlerle incelenmesinde 7 hastada anomali saptanmıştır. Buna rağmen ölçüm yönteminin elenmesi ile 24 hastanın 15'inde anomali saptanmıştır. Bu anomaliler; 3 kohlear hipoplazi, 3 kohlear hiperplazi, 5 lateral semi-sirküler kanal hiperplazisi, bir superior semi-sirküler kanal displazisi, bir posterior semi-sirküler kanal displazisi, beş vestibüler hiperplazi, 5 bitişik internal akustik kanal olarak görülmektedir. Vizüel değerlendirmeye göre sayısal değerlendirmede 8 hastada daha anomali saptanmıştır.

TARTIŞMA ve SONUÇ: TKBT'de vizüel değerlendirmeye sayısal ölçüm tekniğinin eklenmesi SNİK olan hastalarda anomali saptama oranını arttırmaktadır.

Anahtar Kelimeler: Temporal Bilgisayarlı Tomografi, Sensori-nöral İşitme Kaybı, Ölçüm Teknikleri, Anomali

ABSTRACT

INTRODUCTION: The detection rate of moderate inner ear malformations in patients with sensori neural hearing loss (SNHL), can be increased with detailed measurement techniques of high definition temporal bone computed tomography (TBCT), in addition to visual evaluation.

METHODS: Fourtyeight patients who had TBCT between 2008-2010 were included in our study. Twenty-four of these had otological problems without SNHL while the others had congenital SNHL. Axial images were taken with 1,2mm slice thickness with four sequential multidetector CT. Reconstructed coronal images were obtained with 0,6mm slice thickness. The quantitative measurements and visual evaluation of inner ear structures were made and compared between the groups with and without SNHL.

RESULTS: Anomalies were detected in 7 patients with only visual evaluating of the TBCT of SNHL patients. Whereas 15 of 24 patients showed inner ear abnormalities with measurement correlations. These anomalies were; three cochlear hypoplasia, three cochlear hyperplasia, five Lateral Semi-circular Channel hyperplasia, one Superior Semi-circular Channel displasia, one Posterior Semi-circular Channel displasia, five vestibuler hypoplasia, two vestibuler hyperplasia, five narrow internal acustic channel in 15 patients. Quantitative evaluation detected more anomalies in eight patients when compared to visuel inspection.

DISCUSSION AND CONCLUSION: Quantitative measuremet techniques when added to visual evaluation of TBCT in patients with SNHL increased the detection rate of anomalies.

Keywords: Temporal Computed Tomography, Sensorineural Hearing Loss, Measurement Techniques, Anomalies.

INTRODUCTION

Congenital Sensorineural Hearing Loss (CSNHL) is a disease characterised with developmental, structural and functional anomalies and it is encountered by 4-11/10.000 [1]. Inner ear anomalies can be shown by temporal bone computed tomography (TBCT) in 20-30% of the patients [2,3]. Cochlear implantation is the most promising treatment method on patients with CSNHL. Inner ear malformations are evaluated in attempt to decide patient selection and comparison of implamentation direction and technique by using preoperative high resolution temporal bone CT in cochlear implant candidates. In addition, intraoperative risks and postoperative results can be predicted by this method.

While severe inner ear anomalies such as complete labyrinthine aplasia (Michel deformity), cochlear aplasia and single-space deformity are differantiated to a large extent by the evaluation of temporal bone CT with visual inspection; mild deformities such as lateral, posterior, superior semi-circular channel (SCC) displasia and cochlear displasia may go unnoticed solely by visual inspection. The differantiation of these anomalies is increased by measuring normal inner ear structures and obtaining significant standart values.

Our aim in this research was to obtain the normal measurement values of inner ear structures in patients who underwent TBCT without CSNHL and compare them with the findings of patients with CSNHL in order to find out their value in determining inner ear anomalies.
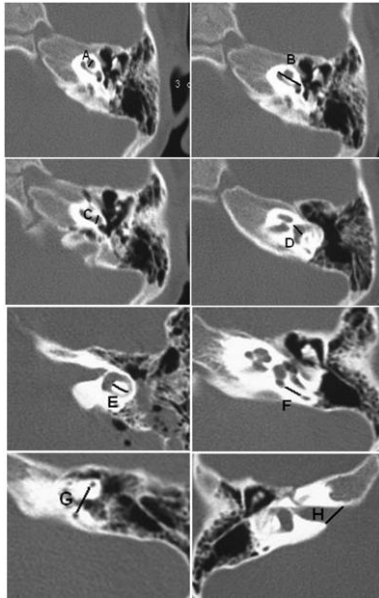
MATERIALS and METHODS

Fourtyeight patients (96 ears) comprising of 24 (48 ears) patients having CSNHL (study group) and 24 (48 ears) patients having otologic problems other than CSNHL (control group) who had TBCT between 2008-2010 were included in this study. Inner ear structures were evaluated with CT examination using quantitative measurement and anomalies were scrutinized with visual inspection. The control group was comprised of 10 male and 14 female patients and their average age was 35.6 (between 10-66). The study group was compromised of 11 male and 13 female patients and their average age was 23.26 (between 2-58).

The TBCT was obtained with high resolution slices by 4-serial (Marconi MX8000; Philips, Amsterdam, The Netherlands) Multidetector CT in all cases. Consecutive slices were obtained with 1.2 mm slice thickness parallel to hard palate on axial plan and reformatted displays were obtained on coronal plan with 0.6 mm slice thickness. The parameters for the examination were: 120 kV and 150 MAS, 512x512 matrix, 3000 window width and 300 window level. The slices were started 1cm below the external ear upper layer while the patients were in supine position with the chin in flexion. The whole petrous bone and mastoid cells were included in the slices.

Eight meauserements from each inner ear were taken on axial images. Cochlear basal turn length, basal turn height where seen in its maximum, apical turn height where lumen diameter was widest, vestibule width in its widest point, superior semi-circular channel bone island width where parallel to cochlear basal turn and in its widest portion, lateral semi-circular channel bone island width where distance between anterior and posterior portions is maximum, posterior semi-circular channel island width where the widest distance is observed within the whole channel, internal acoustic channel (IAC) gap width where the distance between medial and lateral arms is maximum, IAC where it is widest parallel to posterior channel (fig.1).

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Figure 1: Measurement technique on axial plane; A: cochlea apical turn height, B:cochlea basal turn length, C: cochlea basal turn height, D: vestibule width, E: LSCC bone island width, F: PSCC bone island width, G: SSCC bone island width, H: IAC opening width.

Eight different meauserments in the coronal plane were taken as follows: cochlear height and vestibule width where they were widest and parallel to oval window, width of superior semi-circular channel and lateral semi-circular channel bone island, IAC gap and mid-point width at its widest width where the vestibule is seen on the slice, IAC length on slices where its width is at maximum and visibility of the whole canal is available from IAC gap to falciform crest (Fig. 2).
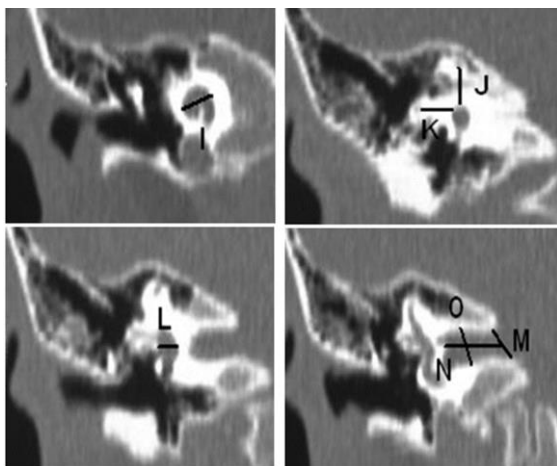
Figure 2: Measurement technique on coronal plane; I: cochlea height, J: SSCC bone island width, K: LSCC bone island width, L: vestibule width, M: IAC opening width, N: IAC length, O: IAC mid-point width.

All patients were evaluated for visual abnormalities. The reader was blinded to the results of visual abnormalities reported. All the results of measurements were compared with the found visual abnormalities.

TBCT inner ear measurments of twentyfour patients without SNHL were taken as controls.

The statistical analyses were made with Statistical Package for the Social Sciences (SPSS) software version 17 (SPSS, Chicago, IL). The average and standart deviation values of the control group were obtained and compared with the study group.

RESULTS

The results of the measurements of the study group is shown in Table 1 and 2. The average values and SD of control group is given in Table 3. The normal values ranges according to the measurement of control group on axial plan are like as follow; cochlea basal turn length 7.61-9.41 mm, cochlea basal turn height 1.38-2.71 mm, cochlea apical turn heigh 2.09-3.17 mm, vestibuler width 3.54-4.7 mm, Superior Semi-circular Channel (SSCC) bone island width 3.64-6.60 mm, Lateral Semi-circular Channel (LSSC) bone island width 2.49-4.69 mm, Posterior Semi-circular Channel (PSSC) bone island width 2.69-6.09 mm, IAC opening width 5.35-9.43 mm, on coronal plan; cochlear height 4.32-5.64 mm, vestibule width 2.51-3.75 mm, SSCC bone island height 4.08-5.96 mm, LSCC bone island width 2.88-4.2 mm, IAC opening width 3.2-6.92 mm, IAC midpoint width 3.2-6.5 mm, IAC length 6.7-14.26 mm. This values are compatible with the study of Chen et al [1]. The inner ear anomalies and their values at coronal and axial plans were listed in Table 4.

Table 1: Measurements of Inner Ear of Patients with Sensorineural Hearing Loss on Axial Plane.

Parameter (mm)	Side	Minimum	Maximum	Mean
Basal turn length	R	0	9.6	8.12
	L	0	9.5	7.98
Basal turn height	R	0	3	1.85
	L	0	3.1	1.8
Apical turn height	R	0	3	2.28
	L	0	3	2.28
Vestibuler width	R	3	4.9	3.82
	L	0	4.4	3.85

SSCC bone Island width	R	0	6.8	4.73
	L	0	6.7	4.7
LSCC bone Island width	R	0	5.1	3.65
	L	0	5.8	3.7
PSCC bone Island width	R	0	5.3	4.2
	L	0	5.7	4.31
IAC width	R	3.2	11.9	6.62
	L	3.8	12.9	7.32

Abbreviations: SSCC: Superior Semi-circular Channel, LSCC: Lateral Semi-circular Channel, PSCC: Posterior Semi-circular Channel, IAC: Internal AcusticChannel

In the control group twelve of the patients had otitis media, 1 had cholesteatoma and 11 did not have any abnormality on CT examination. A high-located jugular bulb was determined in 4 of these patients.

In the study group 7of 24 patients showed inner ear abnormalities with only visual evaluation whereas 15 of 24 patients showed inner ear abnormalities with measurement correlations.

Table 2: Measurements of Inner Ear of Patients with Sensorineural Hearing Loss on Coronal Plane.

Parameter (mm)	Side	Minimum	Maximum	Mean
Cochlea height	R	0	6	4.9
	L	0	6.1	4.98
Vestibule width	R	2.1	4	3.23
	L	0	3.7	3.08
SSCC bone Island width	R	0	7.4	4.73
	L	0	7.1	4.68
LSCC bone Island width	R	0	5	3.45
	L	0	5.3	3.28
IAC opening width	R	2.4	6.8	4.72
	L	2.9	6.9	4.93
IAC mid-point width	R	1.1	6.2	4.34
	L	1.8	6.1	4.53
IAC length	R	8	14.8	10.64
	L	8	15.4	10.78

Abbreviations: SSCC: Superior Semi-circular Channel, LSCC: Lateral Semi-circular Channel, IAC: Internal AcusticChannel

The cochlear height below 4.3mm was regarded abnormal and refered as cochlear hypoplasia compared to the values of control group. Three ears in two patients showed cochlear hypoplasia while visual evaluation showed hypoplasia only in two ears in one patient. The other patient with single side cochlear hypoplasia was detected by using measurment techniques.

Measurement of cochlear height in coronal plan over 5.7 mm was regarded as cochlear hyperplasia compared to the values of control group. Cochlear hyperplasia was detected in two patients (3 ears) where visual evaluation was normal in all (Fig. 3).

Left cochlea, vestibule and semisircular channels were not observed in one of the patients. All of them were detected by using visual inspection. Michel Anomaly is excluded based on patient's normal promontorium size. She was diagnosed as labyrinthis ossificans. Cochlear implant application was not performed in this patient. One patient had bilateral cochlear and vestibular hypoplasia and showed absence of semisircular channels both with quantitative and visual evaluation. This patient was evaluated as labyrinthis ossificans with a meningitis history.

The width of LSCC bone island over 4.72 mm in axial plan and over 4.2 mm in coronal plan, was accepted as LSCC bone island hyperplasia when compared to the control group. LSCC bone island hyperplasia is determined solely, quantatively in 3 of the cases (5 ears) (Fig. 4). SSCC bone island width lower than 3.64 mm in axial plan and lower than 4.08 mm in coronal plan was defined as SSCC dysplasia. SSCC dysplasia was detected only with quantitative measurement in one case (1 ear). Hypoplasia in the right middle ear ossicles and sclerosis in bilateral mastoid cells were determined by visual evaluation in this case.

PSCC bone island width lower than 2.3 mm in axial plan was defined as PSCC displasia. PSCC displasia in the right ear was found in one case who did not show any pathology on visual evaluation (1 ear).

Vestibule width lower than 3.53 mm in axial plane and lower than 2.51 mm in coronal plane was defined as vestibule hypoplasia when compared to control group. Vestibular hypoplasia was detected in three patients (5 ears). Vestibule hyperplasia was detected in two cases by using measurment techniques. All of these anomalies were not determinated by visual inspection.

Internal acoustic channel narrowing term was used for cases with mid point width in coronal plan lower than 3.2 mm when compared to the control group. Three of cases (five ear) showed internal acustic channel narrowing, one of them (2 ears) was detected by visuel inspection but the others (3 ears) were detected by using meaurment techniques. IAC midpoint width in first case was 1.1 mm in right, 1.8 mm in left in coronal plane in the first and 3 mm in right; 2.9 mm in left in the second case, 2.9 mm in right in the third case.
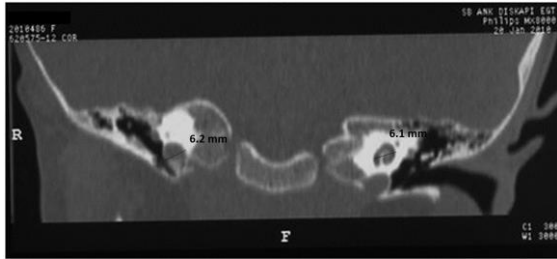
Figure 3: Coronal CT scan demonstrating bilateral cochlear hyperplasia. Each of these hyperplasias was identified by measurment. Cochlea was measured 6.2 mm on the right side and 6.1 mm on the left side.
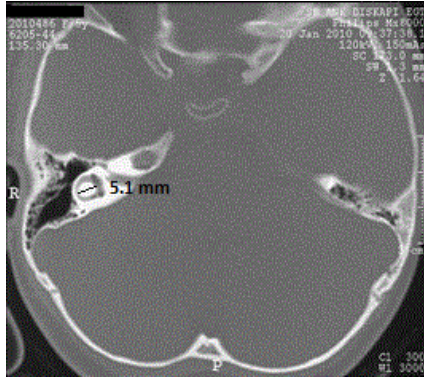
DISCUSSION

Computed tomography preserves its property to be primarily preferred method in our day for the determination of convenience of cochlear implant candidate with hearing loss [4-6]. Inner ear abnormalities can be detected with temporal bone CT in 20-30% [2,3] of the patients with sensorineural hearing loss. Cochlear implantation is a treatment method envisaged for assistance to hearing and talking in these patients [7]. The identification of inner ear abnormalities takes an important role in evaluation of the patient's suitability to implant placement. Detection of abnormalities can also help selection of the surgical procedure and prevention of possible complications [4,7-8]. Malformations like Michel's, cochlear aplasia and common cavity are identified easily by visual evaluation of CT findings but these consist only 1% of the anomalies in these patients [2]. On the other hand, visual evaluation is not adequate for detecting malformations like cochlear hypoplasia or LSSC dysplasia [9]. In this study, we aimed to determine the normal values of inner ear structures in two CT planes and compare them with the results in SNHL patients. Obtained

values are deemed compatible with the measurement analyses in the research of Shim et al [10].

Table 3: Measurements of patients without sensorineural hearing loss.

Parameter	Control	Minimum (mm)	Maximum (mm)	Mean (mm)	Std. Deviation
Cochlea basal turn length (axial)	48	7.70	9.40	8.5304	0.46326
Cochlea basal turn height (axial)	48	1.40	2.20	1.7870	0.19956
Apical turn heigth (axial)	48	2.20	3.50	2.6348	0.27586
Vestibule width (axial)	48	3.60	4.50	4.1209	0.29542
SSCCbone island width (axial)	48	4.60	6.60	5.1243	0.74504
LSCCbone island width(axial)	48	3.00	4.80	3.5917	0.55593
PSCC bone island width(axial)	48	2.40	5.80	4.3957	0.85608
IAC opening width (axial)	48	5.40	9.40	7.3957	1.02284
Cochlea height (coronal)	48	4.40	5.70	4.9804	0.33941
Vestibule width (coronal)	48	2.50	3.90	3.1348	0.31551
SSCC bone island height(coronal)	48	4.10	6.50	5.0217	0.47813
LSCC bone island width (coronal)	48	2.10	4.20	3.5413	0.33725
IAC opening width (coronal)	48	3.20	6.90	5.0630	0.93223
IAC mid-point width (coronal)	48	3.20	6.70	4.5674	0.90825
IAClength (coronal)	48	7.20	13.40	10.4848	1.89455

Abbreviations: SSCC: Superior Semi-circular Channel, LSCC: Lateral Semi-circular Channel, PSCC: Posterior Semi-circular Channel, IAC: Internal AcusticChannel

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Figure 4: Axial CT scan demonstrating LSCC hyperplasia of right ear. This anomaly was identified by measurement only. LSCC bone island width was measured 5.1 mm on the right side.

Table 4: The Inner Ear Anomalies and Their Values in Axial and Coronal Planes

	AXIAL	CORONAL
Cochlear hypoplasia	_	<4.3
Cochlear hyperplasia	_	>5.7
LSSCboneisland hyperplasia	>4.72	>4.2
SSSC displasia	<3.87	<4.08
PSSC displasia	<2.3	_
Vestıbul hypoplasia	<3.53	<2.51
Vestıbul hyperplasia	>4.75	>3.77
IAC stenosis	_	<3.2

Cochlear hypoplasia and incompletely partitioned cochlea (IPC) may be associating anomalies in patients with sensorineural hearing loss. Visual evaluation of CT findings may show a normal cochlea in cases where a hypoplasic or hyperplasic chochlea is present. We found the upper and lower limits for a cochlea as 4.7 and 4.3 mm respectively. Our findings for a cohlear hypoplasia was similar to Shim et al and Purcell et al who have defined the lower limit for cochlea as 4.45 mm, 4.27 mm respectively. In our study; cochlear hypoplasia was defined in 2 patients (3 ears). One patient (1 ear) was detected by using measurment technique only but the other one (2 ears) was detected by visual inspection as well. Cochlea basal turn height measurements done in axial plane were within normal ranges in both patients with cochlear hypoplasia. Besides, basal turn length was normal in one (one ear), but below normal in one (two ears) of these patients on axial images. Hovever cochlear height measurements in coronal plane were below normal in both patients (three ears). This shows that coronal plane is more reliable in determining cochlear hypoplasia. Similiarly Purcell et al stated that coronal planes were more suitable for these measurements [11].

Cochlear implantation is possible in patients with cochlear deformity, however detection of these deformities has a great value in prevention of perilymphatic leak during the operation [12]. On the other hand stimulatory neural elements do not exist along modiolus and selection of eloctrode designs that track along the outer cochlear wall becomes important instead of the ones with modiolus hugging [13].

In three patients (5 ears) with CSNHL, cochlear hyperplasia was detected. All of these patients were determined quantitatively only. However there is no evidence about the effect of cochlear hyperplasia on hearing loss. Purcell et al state in their study that cochlear hyperplasia is not a determiner in severe hearing loss cases [14].

Internal acoustic channel width is also important as it indicates cochlear nerve development in cochlear implant candidates. Measurment of IAC showed high variabilty among patients in our study. Shim et al [10] reported that determining IAC anomalies was diffucult using only CT because of large variability in measurments of IAC. We have measured the mid point of IAC and we believe that this measurement point lessens the variations among measurements (Table 3). Midpoint width of IAC in coronal plane should be more than 3.21 mm according to Shim et al [10]. We have found the lower limit of mid point width 3.20 mm similar to their findings. IAC was narrow in three of our cases. Two of these 3 cases (two ears) were only detected quantatively where visual evaluation was normal. The last case (two ears) was detected with both methods. A narrowed IAC is beleived to be the reason of aplasia of the vestibulocochlear nerve and considered as a contraindication for cochlear implantation [15-17]. Detection of narrow IAC is important, as these cases need a proof for the presence of vestibulocochlear nerve with MR imaging to prevent failure of cohlear implantation.

There is a question about the correlation of hearing loss and inner ear anomalies. Purcell et al [11], state that LSCC malformations are important, as they may be the main cause of hearing loss in these patients. They studied CSNHL patients with mixed type hearing loss

and they claimed that LSCC and cochlea measurements were most definitive ones for defining hearing loss. However on their later study [14] they stated contrarily that correlation of hearing loss with cochlear hypoplasia or hyperplasia was better than LSCC bone island width. LSCC hyperplasia was detected in three cases in this study. We had only one case with isolated LSCC hyperplasia. Although LSCC measurement was definitive in this single case, it is not enough to support the earlier statement of Purcell et al [11]. The other two patients had accompanying cochlear anomalies.

The detection of vascular malformations in patients with CSNHL is important in guiding the surgeon before operation. All of these anomalies can be detected with visual evaluation alone. In this study two high located jugular bulb, one aberrant internal carotid artery and one anterior relocation of sigmoid sinus were detected.

The main limitation of this study was relatively small number of patients. In the evaluation of temporal bone CT of 24 patients who have sensorineural hearing loss, different anomalies were detected in 15 patients with the addition of detailed measurement techniques while only 6 patients were defined with visual evaluation. Measurement methods, particularly increases the detection rate of medium severity anomalies such as semisircular channel displasia and cochlear hypoplasia. In conclusion; preoperative evaluation of temporal bone CT in CSNHL patients is important in order to decide surgery method, prevent complications and evaluate the conformity of the patient for implantation. Usage of quantitative measurement methods with visual evaluation increases the detectability rate of anomalies. We believe that further studies with higher number of patients will provide us the data that will specify the exact necessary measurements that define the anomalies causing hearing loss in CSNHL patients.

Conflict of interest disclosure

The authors declare that there have no financial support and they have no conflict of interest.

REFERENCES

1. Chen JL, Gittleman A, Barnes PD, Chang KW (2008). Utility of temporal bone computed tomographic measurments in the evaluation of inner ear malformations. Arch Otolaryngol Head Neck Surg; 134(1): 50-6

2. Jackler RK, Luxford WM, House WF, et al (1987). Congenital malformations of the inner ear: A classification based on embriogenesis. Laryngoscope; 47: 2-14.

3. Antonelli PJ, Varela AE, Mansuso AA, et al (1999). Diagnostic yield of high resolution computed tomography for pediatric sensorineural hearing loss. Laryngoscope; 109: 1642-7.

4. Witle RJ, Lara JI, Driscoll LW, et al (2003). Pediatric and adult cochlear implantation. Radiographics; 23: 1185-9.

5. Akdaş FV (2012). Çocuklarda sensorinöral işitme kaybı ve odyolojik değerlendirme. Turkiye Klinikleri J E.N.T.-Special Topics; 5(2): 32-42

6. Saton B, Mukherji SK, Telian SA, et al (2003). Congenital aplasia of the semicircular canals. Otol Neurotol; 24(3): 437-46.

7. Lawson JY, Carenley K, Joner JG, et al (1998). Digital imaging: a valuable tecnique for the postoperative assesment of cochlear implantation. EurRadiol; 8: 951-4.

8. Shpizner BA, Holliday RA, Roland JT, Cohen NL, Waltzman SB, Shapiro WH (1995). Postoperative imaging of the multichannel cochlear implant. AJNR Am J Neuroradiol; 15: 1517-24.

9. Woolley AL, Oser AB, Lusk RP, Bahadoni RS (1997). Preoperative temporal bone computed tomography scan and its use in evaluating the pediatric cochlear implant candidate. Laryngoscope; 107: 1101-6.

10. Shim HJ, Shin JE, Chung JW, Lee KS (2006). Inner ear anomalies in cochlear implantees: Importance of radiologic measurements in the classification.Otol and Neurol; 27: 831-7.

11. Purcell D, Johnson J, Fischbein L, Lalwani AK (2003). Establishment of normative cochlear and vestibular measurements to aid in the diagnosis of inner ear malformations. Otolaryngol Head Neck Surg; 128(1): 78-87.

12. Lo WW. Imaging of cochlear and auditory braİn stem implantation (1998). AJNR; 108: 383-94

13. Wootten CT, Backous DD, Haynes DS, et al (2006). Management of cerebrospinal fluid leakage from cochleostomy during cochlear implant surgery. Laryngoscope Nov;116(11):2055-9.

14. Purcell D, Fischbein NJ, Patel A, Johnson J, Lalwani AK (2006). Two temporal bone computed tomography measurements increase recognition of malformation and predict sensorineural hearing loss. Am J LaryngolRhinol; 116(8): 1439-46.

15. Ferreira T, Shayestehfar B, Lufkin R, et al (2003). Narrow, duplicated internal auditory canal. Neuroradiology; 45(5): 308-10. Epub 2003 Mar 22.

16. Cho YS, Na DG, Jung JY, Hong SH (2000). Narrow internal auditory canal syndrome: parasaggital reconstruction. J Laryngol Otol;114(5): 392-4.

17. Shelton C, Luxford WM, Tonokawa LL, Lo WW, House WF (1989). The narrow internal auditory canal in children: a contraindication to cochlear implants. Otolaryngol Head Neck Surg; 100(3): 227-31.