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tartışma ve Sonuç: TBCT’de vizüel değerlendirmeye sayısal ölçüm tekniğinin eklenmesi SNKL olan hastalarda anomalı saptama oranını arttırmaktadır.

Anahtar Kelimeler: Temporal Bilgisayarlı Tomografi, Sensöri-nöral İşitme Kaybı, Ölçüm Teknikleri, Anomalı

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: Fortyeight 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 visual inspection.

DISCUSSION AND CONCLUSION: Quantitative meausretmet 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 implantation 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 differentiated 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 differentiation 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 measurements 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).
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 measurements of twenty-four 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 standard 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 height 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, LSSC 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. These 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 |
| Vestibular width | R    | 3       | 4.9     | 3.82 |
|                 | L    | 0       | 4.4     | 3.85 |

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: LSSC bone island width, F: PSSC bone island width, G: SSCC bone island width, H: IAC opening width.

Figure 2: Measurement technique on coronal plane; I: cochlea height, J: SSCC bone island width, K: LSSC bone island width, L: vestibule width, M: IAC opening width, N: IAC length, O: IAC mid-point width.
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 7 of 24 patients showed inner ear abnormalities with only visual evaluation whereas 15 of 24 patients showed inner ear abnormalities with measurement correlations.

The cochlear height below 4.3 mm was regarded abnormal and referred 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 measurement 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 semicircular 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 semicircular 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, quantitatively 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 dysplasia. PSCC dysplasia 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). Vestibular hyperplasia was detected in two cases by using measurement techniques. All of these anomalies were not determined by visual inspection.

| 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 midpoint 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, PSCC: Posterior Semi-circular Channel, IAC: Internal Acoustic Channel

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

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Table 2: Measurements of Inner Ear of Patients with Sensorineural Hearing Loss on Coronal Plane.
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 acoustic channel narrowing, one of them (2 ears) was detected by visual inspection but the others (3 ears) were detected by using measurement 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.

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 height (axial)      | 48      | 2.20         | 3.50         | 2.6348    | 0.27586       |
| Vestibule width (axial)          | 48      | 3.60         | 4.50         | 4.1209    | 0.29542       |
| SSCC bone island width (axial)    | 48      | 4.60         | 6.60         | 5.1243    | 0.74504       |
| LSCC bone 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        | 10.484/8  | 1.89455       |

Abbreviations: SSCC: Superior Semi-circular Channel, LSCC: Lateral Semi-circular Channel, PS CC: Posterior Semi-circular Channel, IAC: Internal Acoustic Channel
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  |         |
| LSSC bone island         | >4.72 | >4.2    |
| hyperplasia              |       |         |
| SSCS displasia           | <3.87 | <4.08   |
| PSSC displasia           | <2.3  |         |
| Vestibul hypoplasia      | <3.53 | <2.51   |
| Vestibul 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 cochlea is present. We found the upper and lower limits for a cochlea as 4.7 and 4.3 mm respectively. Our findings for a cochlear 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 measurement 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. However 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. Similarly 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 electrode 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. Measurement of IAC showed high variability among patients in our study. Shim et al [10] reported that determining IAC anomalies was difficult using only CT because of large variability in measurements 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 quantitatively where visual evaluation was normal. The last case (two ears) was detected with both methods. A narrowed IAC is believed 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 cochlear 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 dysplasia 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.

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