INNER EAR AND THE COCHLEO-VESTIBULAR NERVE ASSESSMENT ON COMPUTER TOMOGRAPHY IMAGING IN PATIENTS WITH SENSORINEURAL HEARING LOSS

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Rezumat.

The aim of the study is to identify the most common minor malformations encountered in the inner ear and cochlear nerve in patients with profound bilateral sensorineural hearing loss (SNHL) of unspecified cause. **Material and method** Images obtained by CT scan were compared in a control group and a group of patients with bilateral profound SNHL of unspecified cause, to detect the most common anatomical changes in the inner ear and cochlear nerve. **Results and discussions**. Inner ear malformations come in a variety of forms from complete aplasia to subtle hypoplasia of some inner ear elements and adjacent nervous structures contained in the internal auditory canal. Statistics descriptive parameters calculation were obtained for the two groups for each item measured for each ear separately. The existence of anatomical malformations of the inner ear was one proposed factor to be influencing the results after cochlear implantation, but an exact prediction is difficult as there are different other variables involved. **Conclusions.** Simple visual inspection of CT images proves to be insufficient in delivering the best individualized treatment in the pathology of inner ear.

Keywords: *inner ear measurements, individualized treatment, CI results prediction*

Introduction:

Inner ear landmarks are important in evaluation of patients with sensorineural hearing loss (SNHL) especially in establishing the indication of cochlear implantation as well as in the pre-operative planning regarding implant type, electrode architecture, rehabilitation expectations, etc. To evaluate the anatomic architecture of the inner ear measurements on CT axial scans have been conducted.

Material and method:

Images obtained by CT scan were compared in a control group and a group of patients with bilateral profound SNHL of unspecified cause, to detect the most common anatomical changes in the inner ear and cochlear nerve

The control group consisted of 14 randomly selected patients free from ear pathology from the ENT Clinic archive, Clinical Rehabilitation Hospital, which was compared to a study group of 14 patients with congenital bilateral profound SNHL of unspecified aetiology.

Inclusion criteria for the control group consisted of: people free of disease and with

normal hearing; exclusion criteria for the control group were represented by: otitis pathology of any kind (infectious, congenital, traumatic) and patients with hearing loss of any kind, malformations or syndromes manifested by changes in cranio-facial anatomy.

Inclusion criteria for the study group were represented by: patients with profound bilateral congenital SNHL of unspecified cause. Exclusion criteria consisted of: deafness of unknown aetiology (traumatic, infectious, genetic, etc.), progressive or fluctuating hearing loss; malformations or syndromes manifested by changes in cranio-facial anatomy.

In order to characterize the anatomy and imaging characteristics, the inner ear and cochlear nerve anatomy was measured in different landmarks on axial CT slices with high resolution (Philips Briliance with maximal dose of 1069.6; kv:120, mAs:230/300) with the patient positioned to highlight the anatomical elements of the inner ear.

Progressive sections of 1mm were analysed by visual inspection and measured in millimetres (with one decimal) using dedicated imaging software (Philips MxLiteView).

The inner ear anatomical elements were measured as followed:

- Cochlea dimensions (height measured from the base to the top of the cochlea and the basal turn diameter);
- Diameter of modiolus at the second cochlear turn;
- Length and diameter of the posterior semicircular canal;
- Size of the endocranially opening of the endolymphatic fossa;
- Vestibular aqueduct diameter middle portion;
- Diameter of the internal auditory canal at endocranial opening (taken perpendicular to the rear wall);
- Diameter of the bone cochlear nerve channel in the cochlea.

The measurements were performed for each ear separately and the values were analysed separately.

Results:

Measurements resulting after control group evaluation [Tab. 1.]:

- Diameter of modiolus was between 0.9 mm and 1.4 mm, with an average of 1.17 mm;
- Cochlea: height, measured from the base to the tip of the cochlea varied between 3.3 mm and 4.7 mm, with an average of 4.26 and round basal diameter with 5mm and 8mm range from an average of 6.78mm;
- Posterior semicircular canal with a length between 5.6 mm and an average of 6.75mm and 8mm in diameter middle portion between 0.5 mm and 0.8 mm with an average of 0.63mm;
- Endocranial opening of endolymphatic fossa –0.8 mm-1, 7mm with an average of 1.19;
- Vestibular duct diameter: values between 0.4 mm and 0.8 mm with average of 0.64 mm;
- Diameter of the internal auditory canal endocranial opening: values between 3.5 mm and 6 mm with an average of 4.66 mm;
- Diameter of the bony channel corresponding to the cochlear nerve emerging of the cochlea: 1.8 mm and 2.8 mm with an average of 2.2 mm.

Measurements resulting after study group evaluation [Tab. 2.]:

- Diameter of the modiolus was between 0.9 mm and 1.4 mm, with an average of 1.03 mm;
- Cochlea: height measured from the base to the tip of the cochlea varied between 3.3 mm and 5 mm with an average of 4.15 and basal

turn diameter with values between 5.4 mm and 8.2 mm with an average of 7.53 mm ;

- Posterior semicircular canal with a length between 4.5 mm and 8.2 mm with an average of 6.47 mm and diameter in the middle portion between 0.5 mm and 0.8 mm with an average of 0.62 mm;

- Endocranial opening of the endolymphatic fossa 0.8 mm-5, 8 mm with an average of 1.49 mm;

- Vestibular aqueduct diameter middle portion: values between 0.3 mm and 1.4 mm with average of 0.61 mm;

- Diameter of the internal auditory canal opening: values between 3.4 mm and 5.8 mm with an average of 4.7 mm;

- Diameter of the bony channel corresponding to the cochlear nerve emerging of the cochlea: 1.4 mm and 2.2 mm with average of 1.92 mm.

Table 1: Measurements in millimetres obtained for the control group.

	Control	U	Mod	F E	AV	CSP dia	CSP length	Coch dia	Coch high	N. Coch	IAC
1	R I	r	1.2	0.8	0.4	0.5	6.5	5.8	4.4	2.6	3.7
		l	0.9	1.0	0.4	0.6	6.2	5.8	4.5	2.6	3.9
2	L F	r	1.2	1.2	0.7	0.6	6.8	8.3	4.5	2.8	4.9
		l	1.2	1.2	0.8	0.7	7.0	7.8	4.4	2.5	6.3
3	M I	r	1.4	1.1	0.6	0.6	7.0	7.4	4.5	2.6	5.0
		l	1.2	1.0	0.6	0.6	7.0	7.4	4.7	2.5	4.3
4	C C	r	1.3	1.6	0.7	0.7	7.1	6.9	4.5	2.3	4.6
		l	1.4	1.7	0.8	0.7	7.2	7.0	4.3	2.3	4.6
5	I A	r	1.3	1.4	0.7	0.7	7.5	7.2	4.3	2.3	4.7
		l	1.2	1.2	0.6	0.6	6.0	6.0	4.3	2.3	4.5
6	P S	r	1.4	1.1	0.6	0.7	7.0	7.5	4.5	2.3	4.3
		l	1.2	1.2	0.7	0.6	7.0	7.5	4.5	2.3	4.3
7	B A	r	1.2	1.2	0.6	0.7	6.4	6.1	3.8	2.2	4.5
		l	1.3	1.1	0.6	0.6	6.4	6.0	3.9	2.0	4.3
8	S A	r	1.0	1.3	0.8	0.6	5.6	5.3	3.6	1.8	3.7
		l	1.2	1.3	0.7	0.6	5.9	5.1	3.3	1.8	5.4
9	B C	r	1.1	1.4	0.8	0.7	7.5	5.8	3.6	2.0	4.4
		l	1.2	1.3	0.7	0.8	7.3	5.4	3.8	2.0	5.5
10	S M	r	1.2	0.7	0.4	0.6	6.5	7.7	4.3	2.2	5.4
		l	1.2	0.8	0.5	0.6	6.5	7.7	4.4	2.2	5.3
11	N R	r	1.2	1.3	0.7	0.6	7.0	8.0	4.6	2.2	5.0
		l	1.2	0.9	0.6	0.6	6.7	7.9	4.7	2.2	4.5
12	B A	r	1.1	1.3	0.6	0.6	7.0	6.9	4.3	1.9	5.7
		l	1.1	1.3	0.8	0.6	6.7	6.7	4.5	2.0	5.7
13	J D	r	0.9	1.2	0.6	0.6	8.0	6.4	4.1	2.0	4.0
		l	1.1	1.0	0.6	0.6	6.7	6.2	4.5	1.8	3.5
14	R P	r	1.0	1.6	0.7	0.7	6.3	7.0	4.3	2.0	3.5
		l	1.0	1.3	0.7	0.7	6.5	7.2	4.3	2.0	4.9
Mean			1.17	1.19	0.64	0.64	6.76	6.78	4.26	2.20	4.66

***Legend**: U = ear (right / left), mod = modiolus, FE = endolymphatic fossa, AV = vestibular aqueduct, CSP dia = diameter of posterior semicircular canal, CSP length = long posterior semicircular canal; Coch Dia = diameter of*

round basal cochlea; Coch High = height cochlea, N Coch = diameter of the bone channel cochlear nerve, IAC = internal auditory canal diameter.

Table 2.: Measurements in millimetres obtained HNS group.

HNS		U	Mod	F E	AV	CSP dia	CSP length	Coch dia	Coch high	N. Coch	IAC
1	L D	r	1	1.1	0.6	0.6	6.7	8	4	2	4.6
		l	0.9	1	0.6	0.6	6.5	7.9	4	2	4.7
2	R M	r	0.9	1	0.6	0.7	4.5	5.4	3.3	1.4	3.8
		l	1	1.1	0.6	0.6	4.7	5.6	3.5	1.4	4.2
3	B A	r	1.3	0.9	0.5	0.5	5.7	8	5	2.2	5.3
		l	1.2	0.9	0.5	0.6	6.1	8	4.8	2.1	5.5
4	I D	r	1.2	0.9	0.5	0.6	6.3	8	4.1	2.1	5.2
		l	1.1	0.9	0.5	0.7	6.5	8	4.2	2.1	5.2
5	N A	r	1.2	1.3	0.6	0.6	6.5	8	4.5	2.1	4.6
		l	1.4	1.3	0.6	0.7	6.5	8	4.6	2.1	4.5
6	T M	r	1.2	1	0.5	0.6	6.3	7.8	4.2	1.9	4.5
		l	1.2	0.9	0.5	0.6	6.3	7.5	4.4	1.8	4.5
7	A N	r	1.1	0.8	0.5	0.6	5.7	8.1	4.9	2.1	4.9
		l	1	0.8	0.5	0.6	5.9	8	4.8	2	4.2
8	B S	r	0.9	5.5	1.4	0.6	6	7.7	4	1.9	3.5
		l	0.9	5.8	1.4	0.8	6.7	7.4	3.9	1.8	5
9	B D	r	1	1.8	0.6	0.7	7.2	7.8	3.8	1.7	4.2
		l	1	1.8	0.7	0.7	7.2	7.6	3.7	2	4.7
10	E I	r	1	1.1	0.5	0.6	6.7	7.8	4.1	2	4.3
		l	1.1	1.3	0.6	0.6	6.8	8.2	4.2	1.8	4.8
11	A M	r	1	1.9	0.7	0.6	5.8	7.1	3.5	1.9	5.8
		l	0.9	2	0.6	0.6	5.7	7.6	4.3	2	5.5
12	B A	r	0.9	1.2	0.6	0.6	7.5	7	3.8	1.8	4.1
		l	1	1.2	0.5	0.7	7.8	7	3.8	1.8	5.1
13	A C	r	0.9	1.2	0.6	0.6	8.2	7.5	4.5	2.1	5.2
		l	0.9	1.5	0.6	0.6	8.1	7.3	4.4	2.1	5.4
14	F A	r	0.9	0.8	0.3	0.6	7	7.5	4	2	5
		l	1	0.8	0.4	0.6	6.5	7.2	4	1.7	3.4
	Mean		1.04	1.49	0.61	0.63	6.48	7.54	4.15	1.93	4.70

Statistics descriptive parameters calculation were obtained (SPSS software) for the two groups for each item measured for each ear separately.

The Kolmogorov Smirnov test was used to see if the parameter values pursued the normal distribution or not. To determine what tests of significance we can then use to compare the values - t test if normal distribution law is respected and otherwise, Mann-Whitney test.

Statistically significant differences in the anatomical measurements were obtained for the following landmarks: modiolus right ($p = 0.018$) and left ($p = 0.019$), basal turn diameter of the cochlea right ($p = 0.036$) and left ($p =$

0.012) and cochlear nerve bony canal diameter right (p = 0.006) and left (p = 0.004).

Following the measurements and statistical analysis of anatomical elements of the inner ear and cochlear nerve we determined following values as normal for the measured landmarks:

Modiolus: right ear - mean 1,17mm and 0,15mm standard deviation (SD); left ear - mean 1,17mm and 0,19mm SD.

Basal cochlear turn diameter: right - mean 6,88mm and SD 0,90mm; left ear - mean 6,69mm and 0,94mm SD.

Auditory nerve: right - mean 2,23mm and SD 0,28mm; left - mean 2,18mm and 0,25mm SD.

Discussion:

Inner ear malformations come in a variety of forms from complete aplasia to subtle hypoplasia of some inner ear elements and adjacent nervous structures contained in the internal auditory canal.

These malformations can exist isolated for a certain anatomical structure, but may also occur in different landmarks or in combination with external and middle ear malformations. Moreover, these mutations can occur in the context of a syndrome (CHARGE, DiGeorge, Pendred, and Waardenburg).

Among the proposed causes for congenital sensorineural hearing loss were listed structural abnormalities, functional or inner ear development [1]. Identification of exact premises malformations cannot be achieved by examining the patient [2].

Among patients with congenital SNHL a percentage of 25% were reported having inner ear malformations on temporal bone CT images [3].

Obvious malformations (labyrinth complete aplasia Michel, cochlear aplasia and cochlear single cavity, etc.), easily visible on CT images simply by visual inspection were not the subject of this study and these patients have been excluded from the beginning form the study group. However these malformations account for a very small percentage (1%) of abnormalities on CT in patients with SNHL[4]. The size of various elements of the inner ear is important in surgical but also in medical treatment targeting inner ear structures [5]

Cochlea height values published in literature are 4.4 mm-5.9 mm [6].

Normal values for cochlear nerve bony canal size range from 2.13 mm ± 0.44 [7]. The same author reports for the group of patients with SNHL a range from 1.82 mm ± 0.24.

Some authors report a significant statistically difference for this marker in patients with SNHL (1.82 mm ± 0.24) compared with control group p <0.001, results are consistent with other studies published in the literature [7, 8] and with data obtained from analysis of measurements made in the study group compared with the control group.

The cause of a narrow bony canal of the cochlear nerve is unclear. It is assumed that a poor developing otic vesicle inhibit the normal production of nerve growth factor. This results in excessive neuronal degradation and prevents normal development of cochlear nerve. These abnormalities are translated in an underdeveloped cochlear nerve and reduced size of the bony canal.

Probably bone canal development can be influenced by cochlear nerve size [9]. Lack of adequate stimulus provided by a small cochlear nerve can lead to failure to achieve normal size bone canal containing it [7].

The size of cochlear nerve aperture in patients with congenital SNHL may be useful in predicting outcomes after cochlear implant (CI) surgery rehabilitation, because the size is

supposed to be correlated with cell population of spiral ganglion [10].

In accordance with other studies [11, 12] there have been no significant differences in the size of the internal auditory canal (IAC) between the two groups. For normal values of IAC we have considered the interval between 2mm and 8mm in accordance with studies reported in the literature [9, 11].

In subsequent years, the perfecting of surgical techniques, imaging evaluation options and CI devices, studies show good hearing results after implantation in patients with inner ear malformations. This has led to reassessment of indications and possibilities in cochlear implantation [13-17]. Some studies show comparable results post-implant to those obtained from patients without identified malformations.

The existence of anatomical malformations of the inner ear was one proposed factor to be influencing the results after cochlear implantation, but an exact prediction is difficult as there are different other variables involved.

Some authors believe genetics and imaging have a role in the evolution of speech perception performance in children, and sometimes is considered more important than age at implantation, duration of cochlear implant use or pre-operative residual hearing. Complete evaluation of the SNHL child before cochlear implantation is very important [18].

Conclusions

Inner ear measurements are necessary in deciding surgical technique, type of the device and cochlear implant electrode architecture. Accurate measurement can provide truly individualized surgery and a personalized treatment option for the patient.

Detecting minor anatomic abnormalities can be predictive for the outcomes regarding auditory and verbal rehabilitation and can serve as a pre-operative tool for patients and parents discussions regarding expectations. Also it can be important in decision making for surgery or further diagnosis investigation (additional imaging or electro-physiologic tests).

Simple visual inspection of CT images proves to be insufficient in delivering the best treatment options for individual patients with individual needs.

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