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Full Length Research Paper

Normative Sudanese Cochlea Measurements Using High Resolution Computerized Tomography

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The study is to characterize the cochlear anatomy among Sudanese using high resolution computed tomography (HRCT) imaging concerning the subjects ages and gender. A total of 400 Cochlear images were obtained from the scans of 200 subjects (137 Males and 63 Females), aged 1- 84 years. Cochlea width, height, Cochlea nerve canal width and nerve CT number, Basal turn width, transverse cranial dimension, were all been evaluated. The results showed that the mean left and right Cochlear width measured 5.56±0.58 mm, 5.61±0.40mm, height 3.56±0.36, 3.54±0.36mm, the basal turn width 1.87±0.19mm, 1.88, ±0.18mm, Cochlea nerve canal width 2.02±1.23mm, 1.93±0.20mm, Cochlea nerve CT number 279.41±159.02, 306.84±336.9 Hounsfield unit respectively with no significant differences noted in both sides or genders, while the age was found to have an impact on the transverse cranial dimension, right Cochlea nerve canal width and right Cochlea nerve CT number significantly at p< 0.05. The study concluded that the Cochlea nerve canal width and CT number can be predicted for the Sudanese subjects whose ages were known. HRCT temporal bone imaging is the modality of choice in the investigation of cochlear normal anatomy, which guides the clinicians management of the hearing loss conditions if abnormalities are acknowledged.

Keywords: Cochlea anatomy, Basal turn, HRCT, aging, sex differences

INTRODUCTION

Embryologically the Cochleas and vestibules are formed at the 5^{th} week of gestation (Phelps P D,1992). The membranous Cochleas are developed till it achieves 2.5 turns around the cone-like modiolus which contains the spiral ganglion of the Cochlear nerve by the 7^{th} week (Phelps PD, 1992). The inner ear structures have an adult pattern by the end of the 8th week (Jackler RK et al, 1987). Congenital inner ear abnormality is a major cause of sensorineural hearing loss (SNHL) (Robson CD, 2006). Failure of Cochlea development late in the third week of gestation results in Cochlear aplasia and the vestibule and semicircular canals are either normal, dilated or hypoplastic (Papsin BC, 2005), in Cochlea hypoplasia the size of the cochlea is smaller than normal (Yiin R S Z, 2011).

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Imaging of the Cochlea is difficult because of its small size and spiral character (Phelps P D,1992). Recent improvements in imaging techniques have provided increased inner ear anatomical details, High-resolution Computerized Tomography (HRCT) and Magnetic Resonance Imaging (MRI) are achieved in order to investigate the aetiology of (SNHL) and also to assess patients prior to cochlear implantation. Information provided by both examinations is complementary. Axial CT scans give the best demonstration of the individual coils of the Cochlea (Phelps PD et al, 1990a) and CT allows a precise identification of congenital malformations, temporal bone fractures and Cochlear ossification. It can also be used to analyze the bony canal for the cochlear nerve and the Cochlea; although only (MRI) visualizes the cochlear nerve itself (Westerhof JP et al ,2001). MR can confirm the presence of fluid or fibrous tissues within the Cochlea (Harnsberger HR et al ,1987).

High resolution computed tomography can afford excellence cochlear images which help in the practice of otology. To the best of our knowledge; no local studies have been reported for Sudanese Cochlea measurements. Because extra information and knowledge of cochlear dimensions among Sudanese is important, especially in cochlear implantation and also the effects of age, gender and race have to be understood for the assessment of a measured cochlea as to whether it is normal or pathological, this study aimed to characterize the cochlear anatomy among Sudanese through high resolution computed tomography scan in order to establish reference values of the normative measurements regarding the gender and age.

MATERIALS AND METHODS

Subjects

A total of 200 patients were included in the study. Patient's ages were from 1 year to 84 years Patients were selected randomly for brain (HRCT) scans, the patient's age, gender were recorded. For each patient, a retrospective study was conducted on temporal bone CT scans including (400 Cochleas) right and left ears. Subjects who had Cochlear ossification or the patients for assessment of (SNHL) were excluded. This study was done at Alamal Diagnostic Center and Royal Care Hospital Diagnostic Departments during the period from 2011 up to 2014.

Data acquisition and measurement protocol

The HRCT scans for temporal bones were performed using spiral CT (64 detector row Aquilon ,Toshiba Medical System Corp-Tokyo, Japan) and (Somatom plus 64, Siemens, Erlangen, Germany). A volumetric acquisition was obtained with a slice thickness of 0.5 mm and a reconstruction increment of 0.5 mm, 0.85pitch, FOV of 70mm. The volumetric acquisition allowed multi planar reconstructions. The reconstruction slice was 21mm. A reference plane was determined parallel to the lateral semicircular canal containing the cochlear modiolus, and the canal for the cochlear nerve, the oval window along with the footplate, and the posterior semi-circular canal. Reference slice was computed for each patient and all the measurements were performed exclusively on this plane.

Three cochlear dimensions were measured: the width of the bony canal for the cochlear nerve at the entry of the cochlea (WCN), the height of the cochlea (CH) and the width of the cochlea (CW) was defined as the second turn at the reference slice level. The measurements of the canal were always performed tangentially to the two inferior extremities of the X-shaped modiolus. The height was defined as the length between the tip of the cochlea and the orthogonal projection passing through the middle of the canal measurement. The measurement of the second turn of the cochlea was parallel to the latter. Cranial transverse diameter and Cochlea CT number (Hounsfield) were also been evaluated. This method is similar to the method done by (Natacha Teissier et al, 2010)

All measurements were presented as a mean values in (mm) ± standard deviation (SD) and were performed by the same observer.

Statistical analyses

All data obtained in the study were documented and analyzed using SPSS programme version16. Descriptive statistics, including mean ± standard deviation, were calculated. ANOVA test was applied to test the significance of differences, *p*-value of less than 0.05 was considered to be statistically significant. Linear regression models were performed between age, and the variables which have significant relations including: RT cochlear nerve canal width, RT choclea nerve CT number and cranial transverse dimension, and equations were created.

RESULTS

Table 1. shows the variables mean measurements and standard deviation and *p*- values

Variables	Mean± STDV	*p- value*
Left Cochlea width	5.6±0.6	
Right Cochlea width	5.6±0.4	0.134
Left Cochlea height	3.6±0.4	
Right Cochlea height	3.5±0.4	0.200
Left Cochlea nerve canal width	2.0±1.2	
Right Cochlea nerve canal width	1.9±0.2	0.305
Left Basal turn diameter	1.9±0.2	
Right Basal turn diameter	1.9±0.2	0.827
Left Cochlea nerve CT number	279.4±159.0	
Right Cochlea nerve CT number	306.8±336.9	0.222

p-value of less than 0.05 was considered to be statistically significant.

Table 2. shows the ages, Cranium transverse dimension, Cochlea width, height, Nerve Canal width, Basal Turn width and Cochlea CT Number, ***P- value*** for right and left sides according to gender

Variables	*Gender*	*Mean± Std. Deviation*	*P -value*
Age	Male	37.3±20.5	.099
	Female	42.2±17.9	
Left Cochlea Width	Male	5.6±0.7	.524
	Female	5.5±0.4	
Left Cochlea Height	Male	3.6±0.4	.178
	Female	3.5±0.4	
Left Cochlea Nerve Canal Width	Male	2.1±1.5	.299
	Female	1.9±0.2	
Left Basal Turn Width	Male	1.9±0.2	.420
	Female	1.9±0.2	
Left Cochlea CT Number	Male	277.8±153.1	.831
	Female	282.9±172.4	
Right Cochlea Width	Male	5.6±0.4	.086
	Female	5.5±0.4	
Right Cochlea Height	Male	3.6±0.4	.059
	Female	3.5±0.3	
Right Cochlea Nerve Canal Width	Male	1.9±0.2	.078
	Female	1.9±0.2	
Right Basal Turn Width	Male	1.9±0.2	.688
	Female	1.9±0.2	
Right Cochlea CT Number	Male	322.3±394.6	.341
	Female	273.3±145.8	
Cranium transverse dimension	Male	121.1±9.2	.447
	Female	122.0±4.3	

p-value of less than 0.05 was considered to be statistically significant

Table 3. shows the ages classes, Cranium transverse diameter (CTD) and Left and Right Cochlea measurements for RT and LT sides according to age groups

		Left and Right Cochlea measurements									
Age	***CTD****	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1-12	101.9	5.5	5.5	3.6	3.5	1.9	1.9	1.9	1.8	311.7	618.5
13-24	122.2	5.5	5.4	3.5	3.5	1.9	1.9	1.8	1.9	267.9	308.5
25-36	123.2	5.7	5.7	3.6	3.6	1.9	1.9	1.9	1.9	280.2	292.0
37-48	123.5	5.7	5.7	3.6	3.5	1.9	1.9	1.9	1.9	264.2	244.8
49-60	121.9	5.4	5.6	3.5	3.5	1.9	1.9	1.8	1.9	295.9	298.9
61-72	122.2	5.5	5.6	3.6	3.7	1.9	1.9	1.9	1.9	255.4	290.0
73-84	124.1	5.7	5.7	3.6	3.6	1.9	1.9	1.9	1.9	289.4	231.9

1=left Cochlea width (CW)
2=Right Cochlea width (CW).
3=Left Cochlea height (CH)
4=Right Cochlea height (CH)
5= Left Cochlea nerve canal width (CNCW)
6= Right Cochlea nerve canal width (CNCW)
7=Left Basal Turn width (BTW)
8=Right Basal Turn Width (BTW)
9= Left Cranial nerve CT number (CN *CTN)*
10= Right Cranial nerve CT number (CN *CTN)*
*CTD= Cranium transverse diameter

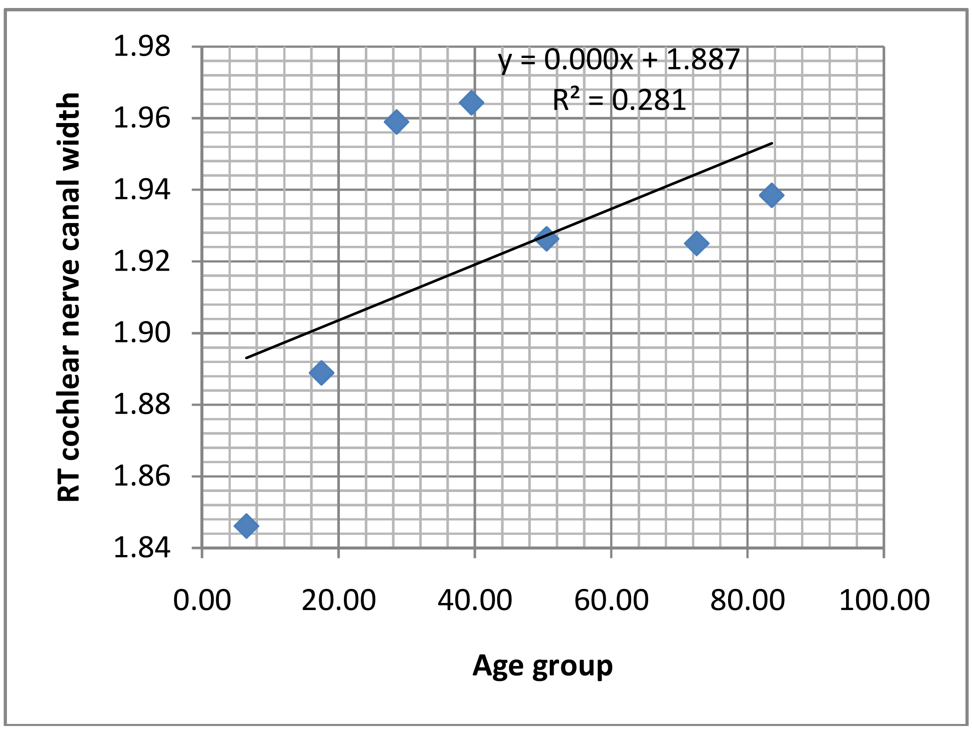

Figure 1. A scatter plot diagramme shows a constructive linear relation between age groups and RT cochlea width .as the age group increased the width increased by 0.0008mm/year starting from 1.9mm ,r^2(0.281)*p* value =.013.

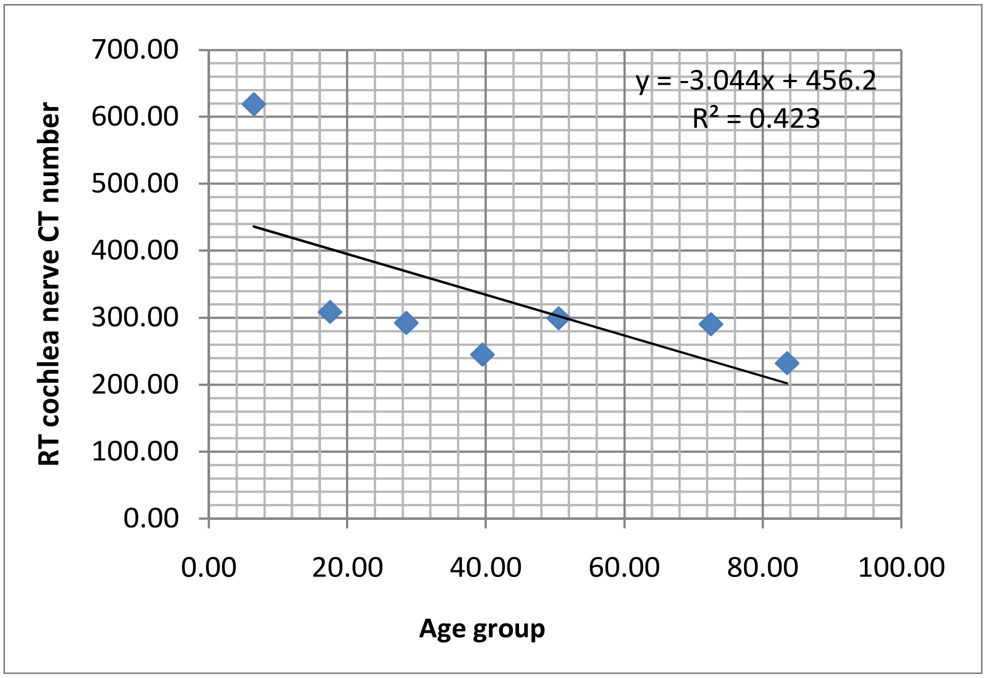

Figure 2. A scatter plot diagramme shows an inverse linear relation between age groups and RT cochlea CT number .as the age group increased the CT number decreased by 3.044mm/year starting from 456.2mm ,r^2(0.423)*p* value =.014

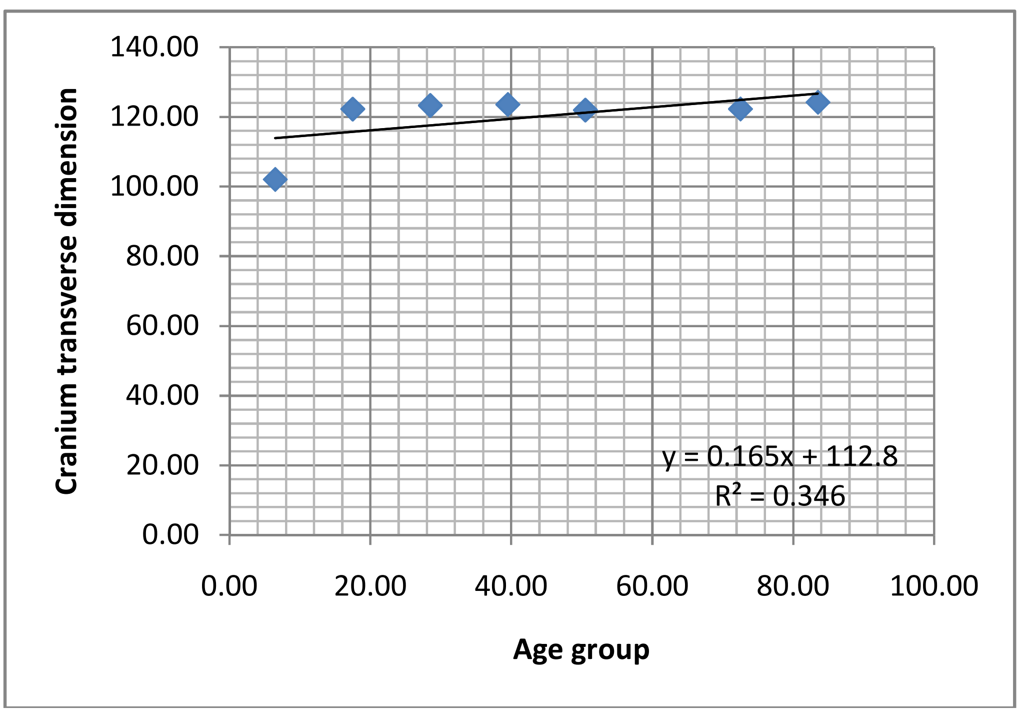

Figure 3. A scatter plot diagramme shows a constructive linear relation between age groups and cranium transverse dimension .as the age group increased the cranium transverse dimension increased by 0.2mm/year starting from 112.8mm ,r^2(0.346)*p* value =.000.

Figure 4. 3D reconstructed CT image of Cochlea and basal turn.

DISCUSSION

Knowledge of the anatomy of the human cochlea is scanty than other sensory systems because of technical difficulties in examining inner ear structures (Adrian F et al, 2011). This study is concerned with normative Sudanese Cochlea measurements Using HRCT, included both genders with mean ages of 37.26±20.48 and 42.24±17.85 years for males and females respectively.

Results showed that the mean left and right Cochlear width measured 5.56±0.58 mm, 5.61±0.40 mm and height measured 3.56±0.36mm, 3.54±0.36mm, the basal turn widths were found to be 1.87±0.19mm, 1.88, ±0.18mm, Cochlea nerve canal widths were 2.02±1.23mm, 1.93±0.20mm, and Cochlea nerve signal intensity (CT number) were 279.41±159.02, 306.84±336.9 Hounsfield respectively, with no significant differences noted in both sides, this was existing in table (1). Our results are consistent to what was acknowledged, that both Cochleas have the same radiological appearance with no significant difference ,and any genetic or embryological defects leading to congenital hearing loss may affect both ears although their size is smaller when compared to normal hearing Cochleas (Natacha Teissier et al, 2010). This reflects the necessity of coming across the normative values in order to discriminate the normal from any pathological conditions.

Many authors have tried to define normative measurements of inner ear structures when assessing SNHL by CT. (Fatterpekar et al. 2000) found a significantly smaller width and height of the bony canal for the cochlear nerve. The importance of our selection of the Cochlea height is that the height contributes to the diagnosis of SNHL as in cases of cochlear hypoplasia or hyperplasia (Purcell DD et al,2006). A thorough knowledge of the normal range of variation of anatomy and topography of the cochlea is necessary for accurate interpretation of the radiographs.

Our study showed that no significant differences were detected between the Cochlea characters in both genders as noticed in table (2).

Table (3) presented the measured variables according to different age classes. The influence of age on the measurements of the cochlea was studied by establishing a graph of the measurements by age for the variables which have significant relations with the age, this was done by applying the ANOVA test using age center as dependent variable, and the group of ages were classified with an interval of 20years. Two of the variables data sets do not vary with age including the cochlea height and width. Three of these variables had significant relation at $p< .05$ with age including cranial transverse dimension as noticed in figure (3), Cochlea nerve signal intensity (CT number), and RT Cochlea nerve canal width, Figures (1, 2). These findings are different to what was mentioned previously in a study done in children that showed the absence of variability with age (Natacha Teissier et al, 2010),on the other hand (McClay et al. 2002) explained a possible fluctuation of height, width measurements with age. Anatomical changes due to aging have been found throughout the auditory system and the hearing problems are caused by changes in the cochlea, eighth nerve, central auditory nervous system due to degenerative anatomical changes (Lynn E Marshall etal,1981). This justifies the findings of this study and changes which had been detected in the auditory nerve CT number to be reduced by age.

Recent improvements in CT imaging technology have facilitated the visualization of the inner ear at resolutions sufficient to review the basic structural anatomy of the cochlea providing possibility to confirm existing knowledge on human Cochlear dimensions, turns, variations and pathology (Adrian F. Fernando et al ,2011). This is the cause of the selection of HRCT scans. Figure (4) shows the 3DCT reconstructed image of cochlea.

In conclusion, new equations were established to predict the Cochlea nerve canal width and nerve signal intensity described by measuring the CT number for the Sudanese subjects whose ages were known.

RT cochlear nerve canal width =0.0008 x age+1.887---------------------------------(1)

RT Cochlear nerve CT number=-3.044 x age+456.2--(2)

Cranium transverse dimension=0.165 x age+112.8---------------------------------------(3)

HRCT temporal bone imaging and 3D reconstruction images for Cochlea can be considered the modality of choice in exploration of cochlear normal anatomy, which guides the clinicians management of the hearing loss conditions if abnormalities are acknowledged.

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