original article

Comparison of cochlear duct length between the Saudi and non-Saudi populations

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BACKGROUND: There are no data on cochlear duct lengths (CDL) among Middle East populations.

OBJECTIVES: The main aims of this study were to estimate the average CDL in the Saudi population and to compare it with the reported CDL in other regions/ethnic groups outside the Middle East.

DESIGN: Retrospective study.

SETTING: Tertiary otolaryngology head and neck surgery center.

SUBJECTS AND METHODS: Temporal bone CT scans were reviewed to determine CDL. We excluded any CT scan of an ear with a congenital inner ear anomaly or acquired pathology.

MAIN OUTCOME MEASURES: CDL.

SAMPLE SIZE: 441 temporal bone CT scans.

RESULTS: The overall CDL mean was 31.9 mm (range 20.3–37.7 mm). The cochleae of males was significantly longer than of females and cochleae from the left side were significantly longer than of the right side. No significant difference was found between children and adults. Inter-study comparison revealed a significant difference in CDL between the Saudi population in our study and European and Australian studies, but not between the present study and North American studies.

CONCLUSIONS: The CDL differed significantly according to side of the cochlea and sex, but not by age. Geographically and ethnically, the mean CDL for Saudis was significantly different from the CDL of subjects of some ethnic backgrounds, but not others. Due to this diversity, we recommend that the CDL be measured before cochlear implant surgery.

LIMITATIONS: All the measurements were done by one person, and the subjects' physical measurements, such as height or head circumference, were not included.

CONFLICT OF INTEREST: None.

Cochlear duct length (CDL) is defined as the length of the scala media measured from the middle of the round window to the helicotrema.[1] Determining the CDL is important for cochlear implantation. The insertion depth of the cochlear implant (CI) electrode array has been strongly associated with intraoperative trauma.[2-4] Shallow insertion is correlated with worse speech performance.[5]

Due to variations in the size of the human cochlea,[6-19] variations in CDL need to be considered before implantation with a fixed length CI electrode. To this end, it would be helpful to know the normal range of CDL in our society. To the best of our knowledge, however, there are no data about the average CDL among the Middle Eastern populations, specifically in the Saudi population. The main aim of this study was, therefore, to estimate the average CDL of the Saudi population, and to compare it with the reported CDL of other nationalities.

SUBJECTS AND METHODS

In this retrospective study, temporal bone CT scans were reviewed to determine CDL. We excluded any CT scan of an ear with a congenital inner ear anomaly or acquired pathology, e.g. post-meningitis or post trauma cochlear ossification. All study procedures were performed at the King Abdullah Ear Specialist Center (KAESC) at the King Saud University in Saudi Arabia. The study was approved by the institutional review board in King Saud University (project number E-16-1917).

The axial views of conventional non-contrast temporal bone CT scans were reviewed using picture archiving and communication system (*https://www.wikiwand.com/en/Picture_archiving_and_communication_system*). The images were reformatted as 1-mm thick minimum intensity projection. CDL was measured using the equation: $CDL=(4.16\times A)-3.98$,[21] where the A value is determined by CT scan as the straight line starting from the midpoint of the round window opening to the opposite side of the cochlea passing through the mid-modiolar axis (**Figure 1**).[15] All measurements were done by the same person. The overall mean and range of CDL were calculated and the mean CDL was compared according to age (children/adolescents ≤18 years or older vs. adults >18 years), sex, and head side (left side cochlea vs. right side cochlea).

The data was analyzed using IBM SPSS version 22 (*https://www.wikiwand.com/en/SPSS*). We tested the normal distribution of the data using the Kolmogorov-Smirnov test. Our data did not follow a normal distribution, so we used a nonparametric test to compare between the groups: the Mann-Whitney Test for independent data (as the sex and age groups) and the Wilcoxon signed ranks test for the dependent data (head side). The overall mean CDL of this study was compared with other published data using independent samples *t* test, using the published summary statistics—mean, standard deviation and sample sizes since the full data from published studies was not available.

RESULTS

In 401 temporal bone CT scans (882 cochleae), the sex distribution was 226 females and 215 males. The age distribution was 383 children (≤18 years) and 58 adults. The mean (SD) age of the children was 7.4 (3.6) years and of adults, 37.2 (14.9) years. The overall mean CDL was 31.9 mm (range 20.5–37.7 mm). According to age, no significant difference between children and adults was found in mean CDL (P=.720) or mean CDL in the right (P=.256) and the left side (P=.819) (**Table 1**).

According to the sex, males had a significantly longer mean total CDL (P=.003), mean CDL in the right side (P=.014), and mean CDL in the left side (P=.003) (**Table 2**). According to head side, the mean CDL in the left side (32.199 mm [2.869]) was significantly longer than in the right side (31.565 mm [2.785]) (P<.0001).

DISCUSSION

In 1938 Hardy was the first to describe the measurement of CDL 6. Subsequently many articles using different methods to measure the CDL have been published. Debate persists about how to measure CDL. In the present study, we measured the CDL by using the equation at the level of the organ of Corti,[21] which is the most applicable and time saving method and it is what we use in the routine practice in our institute.

Many studies have found that CDL is not age dependent.[1,7,11,22] Our findings support this as there was no significant difference in CDL between the age groups. We think that these corresponding findings confirm that the age factor has no role in the field of studying the causes of the CDL divergence.

We compared the mean CDL in the present study with those reported by other studies (**Table 3**). No significant difference was found between the present study and North American studies,[6,7,20,25] except in one article.[11] The mean CDL in European and Australian studies are significantly longer to those obtained in the present study.[1,8,9,12,15,17,22] Three studies reported CDL in Asian populations.[19,24,26] The first study, presented in poster-format, reported a mean CDL of 29.8 mm (28-34.3 mm),[19] the second study reported a significantly smaller CDL than the present study,[26] and the third study, published in 2017 measured the CDL in different Asian ethnic populations (Chinese, Malay, and Indian).

However, unlike some previous studies,[1,22,23] the present study found that CDL differed significantly according to head side, which supports the findings of recent study.[24] Furthermore, whereas many studies have found no significant difference in CDL according to sex,[7,16,20,25,26] we found that males had a longer CDL than females, which, while potentially controversial, is not a unique finding.[1,11,15,24]

The ethnic group of the subjects and the geographical area of the studies are factors to consider in studying CDL diversity. While the average CDL of all racial groups has not been reported, extant reports indicate that there is racial variation between Asia populations. This supports our finding of CDL variations between ethnic group and geographic area.[24] Why this diversity exists is unclear and is possibly due to a combination of factors. The inter-study variety in modality, sample size, and method of CDL measurements in the studies shown in **Table 3** may be partly attributable for the diversity. Furthermore, the physical measurements of the subjects, e.g. height and head circumference, might impact CDL but were not considered in the present study or in the previous studies. We believe that further studies that consider all of these factors are needed to explore this issue.

There are several limitations in the present study. Firstly, all measurements were done by the same person, as we tried to mimic the current practice of the surgeons when they estimate the CDL before surgery. Secondly, the subjects' physical measurements, such as height or head circumference, were not included, although this may provide to be an interesting future study in terms of investigating the relationship between the subjects' physical measurements and the measured CDL, particularly across different ethnic groups.

Finally, future studies will have much to explore variations in cochlear anatomy, specifically CDL, between sex, ethnic groups, and the side of the head. Although conclusions are very much preliminary, that predictable CDL variations do seem to exist underlines the importance of taking a flexible approach to CI insertion depth. Using radiological imaging to predict the CDL before CI surgery to adjust CI insertion depth should help to minimize intraoperative trauma and maximize postoperative speech performance.[2-5]

In conclusion, in our cohort of 882 cochleae, CDL differed significantly according to side of the cochlea and sex but not age group. Geographically and ethnically, the mean CDL of Saudis was significantly different from the CDL of some subjects of ethnic backgrounds but not others. Due to this diversity, we recommend that CDL be measured before cochlear implant surgery.

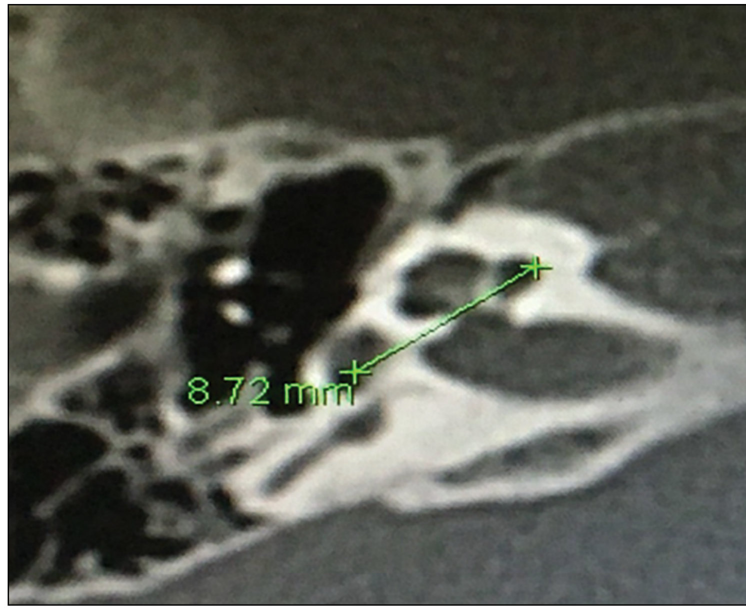

Figure 1. Measurement of the A value in the cochlear duct length equation.

Table 1. Comparison of child and adult cochlear duct lengths (CDL). Total is the average of left and right side.

	Mean CDL (± SD)		
	Overall	Right side	Left side
Children (≤18 y)	31.83 (2.73)	31.48 (2.88)	32.17 (2.932)
Adults (>18 y)	32.24 (1.95)	32.09 (2.06)	32.38 (2.46)
P value	.720	.256	.819

Data are mean (standard deviation) in millimeters. Overall is the average of left and right side.

Table 2. Comparison between male and female cochlear duct length (CDL). Total is the average of left and right side.

Sex	Overall	Right side	Left side
Males	32.27 (2.48)	31.95 (2.61)	32.59 (2.75)
Females	31.51 (2.75)	31.20 (2.91)	31.82 (2.94)
P value	.003	.014	.003

Data are mean (standard deviation) in millimeters. Overall is the average of left and right side.

Table 3. The different reported means of CDL in the various studies.

Authors	Modality	CDL			N	Study location	*P* value
		At the level of	Mean in mm (SD)	Min/Max			
Hardy 1938[6]	Histology	OC	31.57 (2.3)	25.26 / 35.46	68	N America	.3454
Walby 1985[7]	Histology	OC	32.6 (2.1)	30.1 / 36.4	20	N America	.2286
Pollak et al 1987[8]	Histology	OC	28.4 (3.4)	24 / 33.5	9	Europe	.0001
Ulehlova et al 1987[9]	Histology	OC	34.2 (2.93)	28 / 40.1	50	Europe	.0001
Sato et al 1991[11]	Histology	LW	38.64 (3.19)	32.7 / 43.2	18	N America	.0001
Kawano et al 1996[12]	Histology	LW	40.81 (1.97)	37.93 / 43.81	8	Australia	.0001
Kawano et al 1996[12]	Histology	OC	35.58 (1.41)	34.15 / 37.9	8	Australia	.0001
Ketten et al 1998[20]	CT	OC	33.01 (2.31)	29.07 / 37.45	20	N America	.0591
Escudé et al 2006[15]	CT	LW	34.4 (2.2)	30.76 / 37.41	84	Europe	.0001
Stakhovskaya et al 2007[25]	Histology	OC	33.13 (2.11)	30.5 / 36.87	9	N America	.1588
Erixon et al 2009[17]	Plastic casts	LW	42 (1.96)	38.6 / 45.6	58	Europe	.0001
Grover et al 2013[19]	CT	LW	29.8 (N/A)	28 / 34.3	104	Asia	No SD
Shin et al 2013[26]	Micro CT	LW	30 (1.6)	N/A	39	Asia	.0001
Erixon and Rask-Andersen 2013[22]	Plastic casts	LW	42.2 (1.86)	37.6 / 44.9	51	Europe	.0001
Würfel et al 2014[1]	Cone beam CT	LW	37.9 (1.98)	30.8 / 43.2	436	Europe	.0001
Thong et al 2017[24]	CT	LW	Male: 22.32 Female: 21.83	19.71 / 25.09	314	Asia	No Mean, No SD
Present study	CT	OC	31.882 (2.645)	20.45 / 37.72	882	Saudi Arabia (Asia)	N/A

OC=organ of Corti, LW=Lateral Wall, CT=computed tomography, SD=standard deviation, N/A=not available, N=number of subjects in the study, N America=North America.

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